Australian Government
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Defence Science and
Technology Organisation

Proceedings of the 2012 Model-Based Systems Engineering Symposium, 27 - 28 November 2012, DSTO Edinburgh, South Australia

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Weapons Systems Division
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DSTO-GD-0734

ABSTRACT

"*…the future of systems engineering can be said to be model-based*" according to the International Council on Systems Engineering (INCOSE) vision for 2020. Within Australia, Model-Based Systems Engineering (MBSE) is emerging on a greater number of projects and across a broader range of organisations.

The 2012 MBSE Symposium explored the innovative application of MBSE methodologies to *Concept Engineering*. Concept Engineering can be described as the application of systems engineering principles, processes, methods, techniques and tools to the identification and analysis of the needs of capability users and other stakeholders.

The symposium included two keynote presentations and fifteen presentations from DSTO, industry and academia. It also included two workshop sessions that explored the use of capability system models as part of the contracting process.

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1. Introduction

1.1 Overview

"*...the future of systems engineering can be said to be model-based*" according to the International Council on Systems Engineering (INCOSE) vision for 2020.

Within Australia, Model-Based Systems Engineering (MBSE) is starting to emerge on a greater number of projects and across a broader range of organisations. This suggests that there is a greater appreciation of the benefits that MBSE affords a project. An informal symposium on MBSE in 2011[1] was so successful that DSTO again organised an MBSE Symposium in 2012. As a result of feedback from participants, the organising committee retained a similar format for the 2012 Symposium, involving a single stream of presentations, even though this limited the number of papers that could be presented.

The MBSE Symposium held at DSTO Edinburgh, South Australia on 27-28 November 2012, explored the innovative application of MBSE methodologies to *Concept Engineering*. Concept Engineering can be described as the application of systems engineering principles, processes, methods, techniques and tools to the identification and analysis of the needs of capability users and other stakeholders.

The 2012 MBSE Symposium was attended by 88 Australian and international participants, and was streamed live from Edinburgh to DSTO sites in Melbourne and Canberra. It included two keynote presentations and fifteen presentations from DSTO, industry and academia on a wide range of MBSE topics related to Concept Engineering. The symposium also included two workshops that explored the use of capability system models as part of the contracting process.

The organising committee thanks the Defence Systems Innovation Centre (DSIC) for their generous sponsorship, and INCOSE, the Systems Engineering Society of Australia (SESA) and the DSTO Simulation Hub for their support.

1.2 Symposium Contacts

Conference Chair	Kevin Robinson (DSTO)
Technical Chair	Quoc Do (UNISA)
Technical Reviewers	Åse Jakobsson (DSTO), Despina Tramoundanis (DSTO) and Jon Hallett (Deep Blue Tech)
Technical Program Coordinator	Wayne Power (DSTO)
Secretary (General) Secretary (Finance)	Wayne Power (DSTO) and Brendan Kirby (DSTO) Wendy Butler (DSTO)
Symposium Editor	Michele Knight (DSTO)
Social Coordinator	Allison Lang (Aerospace Concepts)
Administration	Rebecca Rocca, Charmae Bell

[1] Rian Armstrong, Editor (2012) *Symposium on Model-Based Systems Engineering Proceedings, Held 24th - 25th October 2011, DSTO Edinburgh*, DSTO-GD-0698

1.3 2012 MBSE Symposium Program

Tuesday 27 November 2012

Time (ADL)	Event or Presentation Title	Presenter	Facilitator
8:30	**Registrations open**		
9:00	Welcome & admin SESA Welcome	Kevin Robinson Mike Ryan	Kevin Robinson
9:30	Keynote: How to eat an elephant – building a constituency for research in simulation and modelling	Andrew Parfitt, University of South Australia	
10:00	Faster, Better, Cheaper – The Fallacy of MBSE?	David Long	
10:30	**Refreshments**		
11:00	Lessons Learned in Introducing MBSE – Post 2009	Peter Campbell	David Harvey
11:30	Theatre of Operations: An Entertaining Problem	Tommie Liddy, Michael Waite, Paul Logan, David Harvey	
12:00	**Lunch**		
12:45	Using MBSE to Understand the Link between Capability Acquisition Projects and DSTO Technology Advice	Simon Demediuk, Wayne Power, Brett Morris	Jon Hallett
13:15	Enhancing the Clarity of Low Level Decisions on the Goals of Large Complex Projects	Robert Dow, Lyn Dow, Kim Baddams, David Kershaw	
13:45	Employing Concept Definition Techniques to Deliver Value on the RAN Air Warfare Destroyer Program	Steven J. Saunders	
14:15	**Refreshments**		
14:45	Workshop 1: What is a 'Capability System Model'? Workshop 2: MBSE Practices Across the Contractual Boundary	WS 1: Mike Ryan WS 2: Quoc Do, Jonathan Hallett	
16:15	Workshop summary presentations and discussion		
17:00	**Close Day 1**		
19:00	**Symposium Dinner - Crowne Plaza**		

Wednesday 28 November 2012

Time	Event or Presentation Title	Presenter	Facilitator
8:30	**Morning coffee/tea**		
9:00	Keynote: Rebuilding the Tower of Babel: Better Communications with Standards	Matthew Hause, Object Management Group	Quoc Do
9:30	A Proposed Pattern of Enterprise Architecture	Dr Clive Boughton	
10:00	Incorporating MBSE into SoS Engineering Practice	Pin Chen, Mark Unewisse	
10:30	**Refreshments**		
11:00	Model Based Systems Engineering – Issues of application to Soft Systems	Ady James, Alan Smith, Michael Emes	Stephen Cook
11:30	The Best of Both Worlds – CORE-based WSAF with DOORS-based Requirements Management	Roger McCowan, Michael Waite	
12:00	A Formal Modelling Language Extending SysML for Simulation of Continuous and Discrete Systems.	Mark Hodson and Nick Luckman	
12:30	**Lunch**		
13:15	Towards the Use of Network Analysis Method In Analysing Node Properties In a System Model	Li Jiang, Hossein Seif Zadeh	Åse Jakobsson, Kevin Robinson
13:45	Streaming transition (switch between sites)		
13:50	Technical Risk Analysis – Exploiting the Power of MBSE	Despina Tramoundanis, Wayne Power, Daniel Spencer	
14:20	**Refreshments**		
14:45	Modelling the Management of Systems Engineering Projects	Daniel Spencer, Shaun Wilson	Despina Tramoundanis
15:15	Potential Benefits of Product Lifecycle Management (PLM) 2.0 Social Networking Capabilities within MBSE	Axel Reichwein, Shaunak Hemant Shroff	
15:45	Closing remarks	Kevin Robinson	
16:00	**Close Day 2**		

2. KEYNOTE 1: How to eat an elephant – building a constituency for research in simulation and modelling

Professor Andrew Parfitt
Pro Vice Chancellor and Vice President, Division of Information Technology, Engineering and the Environment, University of South Australia

Abstract

Research to develop disciplines and capabilities that underpin outcomes for a variety of applications often struggles to gain support from end users, partly due to assumptions made about the utility of the underpinning science or technologies and partly because it is difficult to find a constituency within some application domains to champion the adoption of new techniques. Modelling and simulation and systems engineering are broad areas that seems to fall within this category outside a few recognised communities.

This presentation discusses some of the ways in which the research community might look to engage users in order to develop an understanding of the benefits associated with the adoption of a systems approach, and in particular the use of modelling and simulation in the design, implementation and operations phases of large projects.

Presenter Biography

Professor Andrew Parfitt commenced as Pro Vice Chancellor and Vice President of the Division of Information Technology, Engineering and the Environment in August 2007. Previously, he was the Director of UniSA's Institute for Telecommunications Research (ITR) (2004 - 2007), one of Australia's foremost ICT research organisations.

In 2006 he concurrently acted as Head of the School of Electrical and Information Engineering and led the strategic planning that resulted in the formation of the new Defence and Systems Institute (DASI) and a closer cooperation between our electrical and electronic engineering related disciplines.

Andrew has been a major contributor to the ATN Universities' push to establish and maintain measures of applied research on the research evaluation agenda.

He has a PhD in Electrical and Electronic Engineering from Adelaide University and was an Associate Dean in the Faculty of Engineering there, before joining CSIRO's Telecommunications and Industrial Physics division in Sydney in 1998. Within the CSIRO he led the Space and Satellite Communication Systems team from 2001. During this time he was responsible for fundamental and applied research in areas ranging from radar and communications to satellite systems and radio astronomy technologies.

Andrew has had an outstanding career as a specialist in antenna and radio systems and more recently in areas relating to space science and technology. A graduate in engineering from the

University of Adelaide, he began his professional career with the Defence Science and Technology Organisation before returning to study under a DSTO cadetship.

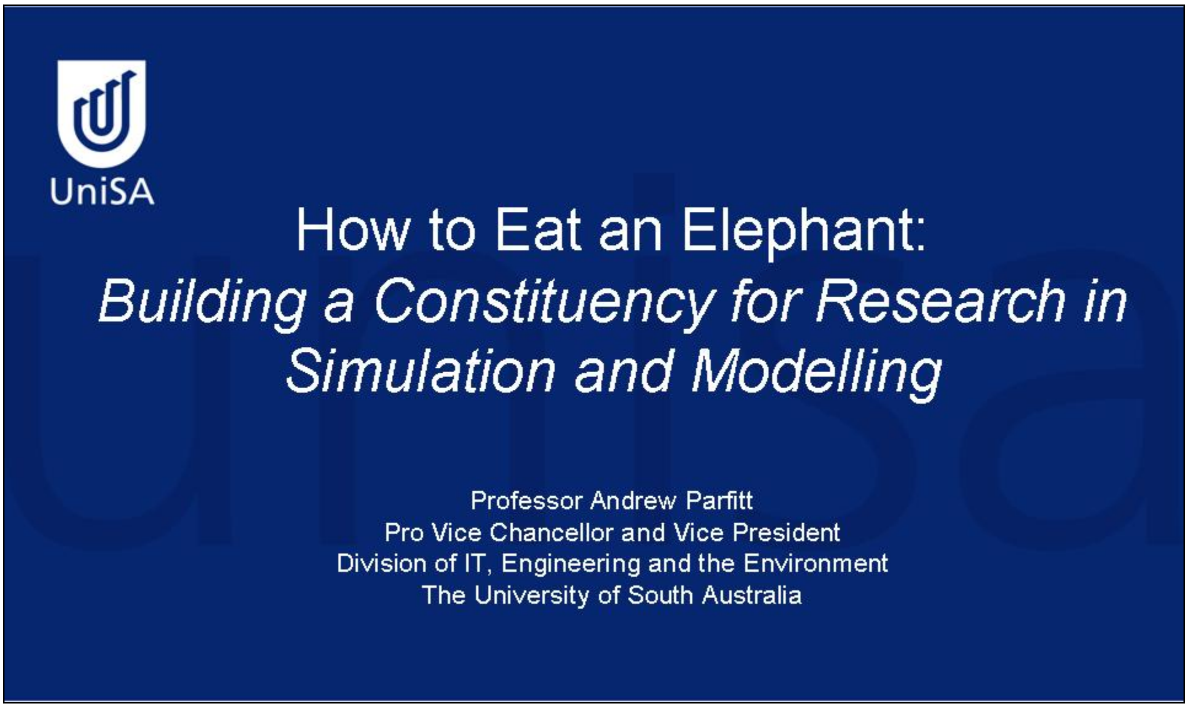
In 2003 Andrew became CEO of the Cooperative Research Centre for Satellite Systems (CRCSS), the national research group responsible for launching FedSat, Australias first satellite in 30 years.

He has held adjunct academic positions at UniSA, the University of Adelaide, the University of Sydney and Macquarie University. In a professional capacity he is a Senior Member of the Institute of Electrical and Electronics Engineers and has been Chair of both its South Australia and New South Wales Sections. He is Chair of the Australian Academy of Science National Committee for Radio Science, and is a Fellow of Engineers Australia.

He is a Board Member of the Defence Teaming Centre and the Technology Industry Association.

In 2010 he was appointed to the Commonwealth Government's Space Industry Innovation Council.

Presentation



The University of South Australia

37,000 students (undergraduate, postgraduate, research)

6,000 International onshore students

3,500 staff (academic, research, professional)

4 Academic Divisions, 4 City Campuses

Business; Health Sciences; Education Arts and Social Sciences; IT Engineering and Environment

A$550m budget, A$60m research income

The Problem of Enabling Disciplines:

What is an enabling discipline?

The Problem of Enabling Disciplines:

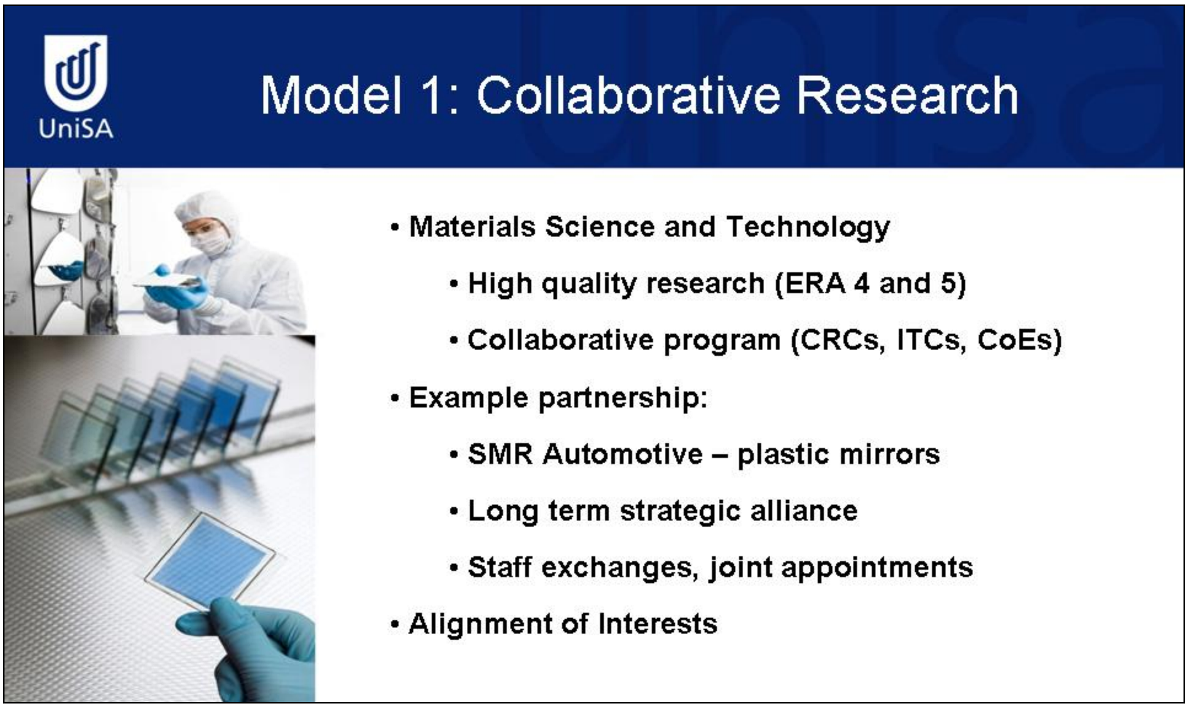
How do you build an enabling discipline?

Challenges

1. **Identity – what is it?**
2. **Utility – what does it do?**
3. **Maturity – does it work?**
4. **Ubiquity – doesn't everyone do it?**

Classic Example - *Statistics*


UniSA
Education and Research: building a foundation
• Education – skills, professions, CPD ...
• Research – knowledge creation, innovation ...
• Engagement –
• Partnerships and collaboration
• Industry alliance programs
• Networks and clusters
• Technology transfer


UniSA
Model 1: Collaborative Research
• Materials Science and Technology
• High quality research (ERA 4 and 5)
• Collaborative program (CRCs, ITCs, CoEs)
• Example partnership:
• SMR Automotive – plastic mirrors
• Long term strategic alliance
• Staff exchanges, joint appointments
• Alignment of Interests

Model 2: Industry Alliance Program

UniSA

- ICT Industry - Sector Wide
- Emphasis on developing *work-ready skills*
- Innovation factory – *bite size real problems*
- Partnership on student projects
- Workplace experience – building familiarity
- Promotion of outcomes

Model 3: Research and Innovation Clusters

UniSA

- Strategic Research Partnerships
- Multidisciplinary challenges
- Extensive consultation and mapping
- Wide participation across UniSA
- Innovative initiatives
  - Zero Waste SA Centre
  - Northern Business Research Partnerships
- From seed funding to major coinvestment

Model 4: Technology Transfer

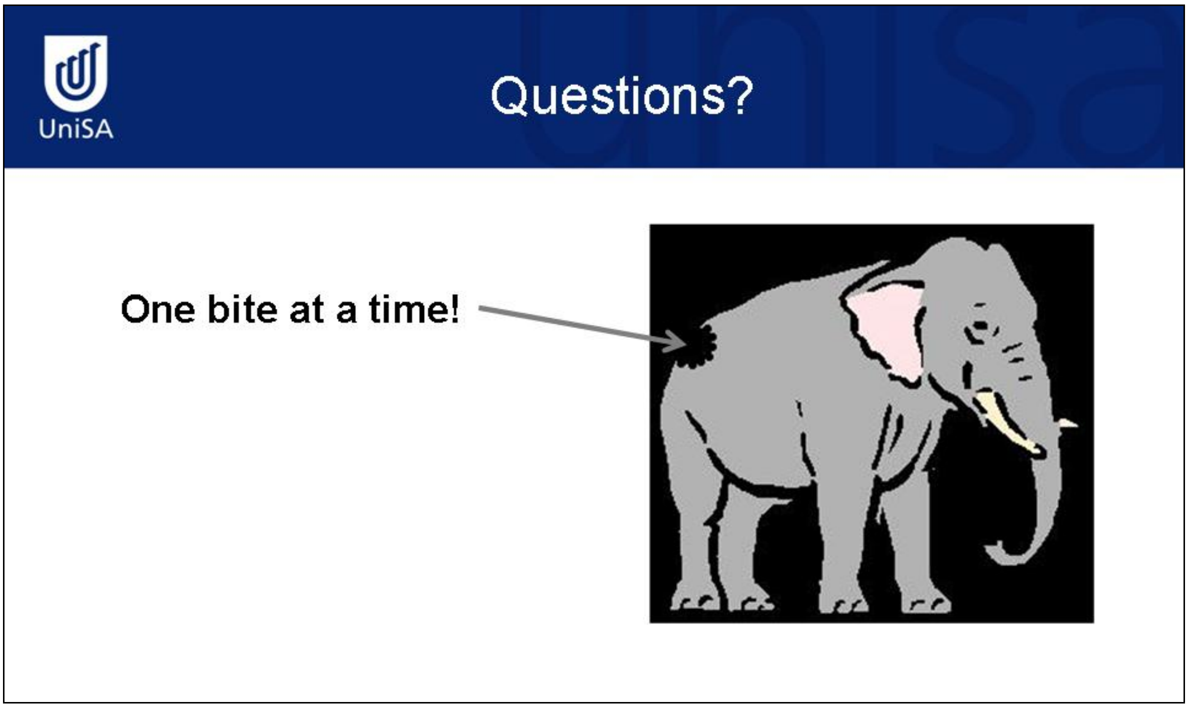
UniSA

- Technology transfer nodes
- Spin out companies
- Joint ventures
- IP licencing
- Incubation
- ITEK

Key Success Attributes

UniSA

- Communication and openness
- Realistic expectations
- Clarity around purpose and outcomes
- Understanding of opportunities
- Leveraging successful models
- Handling Intellectual Property


UniSA
Questions?
One bite at a time!

3. Faster, Better, Cheaper – The Fallacy of MBSE?

David Long
Vitech Corporation

Abstract

Scope, time, and cost – the three fundamental constraints of a project. Project management theory holds that these three dimensions are inextricably linked as competing constraints. To complete a project faster must sacrifice budget or scope (whether explicitly through reduced capability or implicitly through lower quality). Likewise, to complete a project at lower cost inevitably results in longer schedules or reduced capability/lower quality. As the standard saying goes today, "faster, better, cheaper – pick any two".

When Daniel Goldin became Administrator of the US National Aeronautics and Space Administration (NASA), he championed the cause of a unified "faster, better, cheaper" mentality. Using this management mantra, Goldin sought to save money while simultaneously improving performance and accelerating schedule. In other words, he sought to deliver results seemingly impossible given the "iron triangle" of project management. After multiple mission failures including the twin Mars mission disasters in 1999, the concept of faster-better-cheaper was widely derided, and we once again returned to the model of "pick any two".

Today, with the rise of Model-Based Systems Engineering (MBSE), the concept of faster-better-cheaper has re-emerged, albeit under new monikers. The standard INCOSE MBSE briefing (MBSE Workshop, February 2010) promises quality and performance improvements with enhanced rigor and precision, improved stakeholder communication, and better management of complexity. Others tout MBSE's ability to accelerate the systems engineering effort as well as the overall system life cycle.

As we seek to transform the practice of systems engineering to better face the complexities and constraints of today, we must ensure that we maintain our own balance. We must promise improved results in order to justify the cost – and the risk – of adopting new practices. However, we must ensure that we don't over promise and under deliver, or the legacy of MBSE will be landmark failures rather project success. As we seek to justify the adoption of new technologies and new approaches, are we simply falling into an old trap, retracing the steps of Goldin's previous doomed journey? Or, through a skillful blend of systems engineering and project management approaches, can we actually achieve the vision of faster-better-cheaper? If so, what frameworks must we adopt as systems practitioners and what changes must we make as project managers?

Presenter Biography

David Long founded Vitech Corporation in 1992 where he developed and commercialised CORE®, a leading systems engineering software environment used around the world. He

continues to lead the Vitech team as they deliver innovative, industry-leading solutions helping organizations to develop and deploy next-generation systems.

For over twenty years, David has focused on enabling, applying, and advancing model-based systems engineering (MBSE) to help transform the state of the systems engineering practice. He has played a key technical and management role in refining and extending MBSE to expand the analysis and communication toolkit available to systems practitioners. David is a frequent presenter at industry events worldwide delivering keynotes and tutorials spanning introductory systems engineering, the advanced application of MBSE, and the future of systems engineering. His experiences and efforts led him to co-author the book A Primer for Model-Based Systems Engineering to help spread the fundamental concepts of this key approach to modern challenges. In 2006, David received the prestigious INCOSE Founders Award in recognition of his many contributions.

Presentation

The Rise of Faster, Better, and Cheaper (FBC)

- Launched in 1992 by NASA Administrator Dan Goldin
- Sought to improve cost, schedule, and performance simultaneously in developing high tech systems
- Launched 16 missions during an 8 year period
  - 5 missions to mars
  - 1 mission to the moon
  - 3 space telescopes
  - 2 comet and asteroid rendezvous
  - 4 Earth-orbiting satellites
  - 1 ion propulsion test vehicle
- 9 of the first 10 missions succeeded

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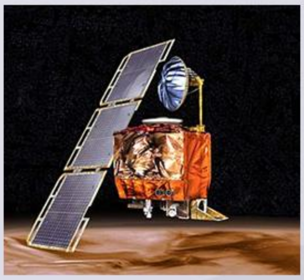
The Fall of FBC – The Twin Mars Mission Disasters of 1999

- Mars Climate Observer
  - Lost communication during orbital insertion
  - Cause of failure: units error (imperial vs metrics) resulted in incorrect atmospheric insertion and disintegration



- Mars Polar Lander
  - Failed to reestablish communication after descent
  - Likely cause of failure: premature engine cut off causing the lander to impact at a high velocity

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The Fall of FBC, cont.

"FBC (resulted in) reduced workforce capability; increased safety risks; and minor oversights that resulted in lost spacecraft."

International Federation of Professional and Technical Engineers, 2003

"FBC should be thrown in the waste basket."

US Senator Kay Bailey Hutchinson, 2003

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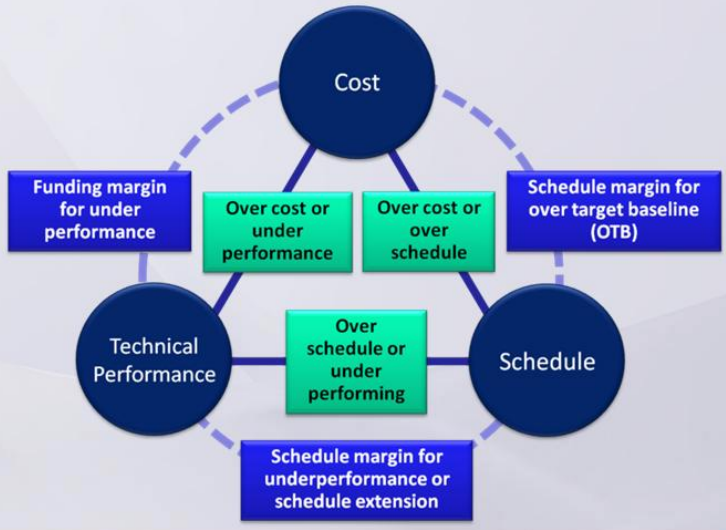
The "Iron Triangle" of Project Management



Today's management mantra – "pick any two"

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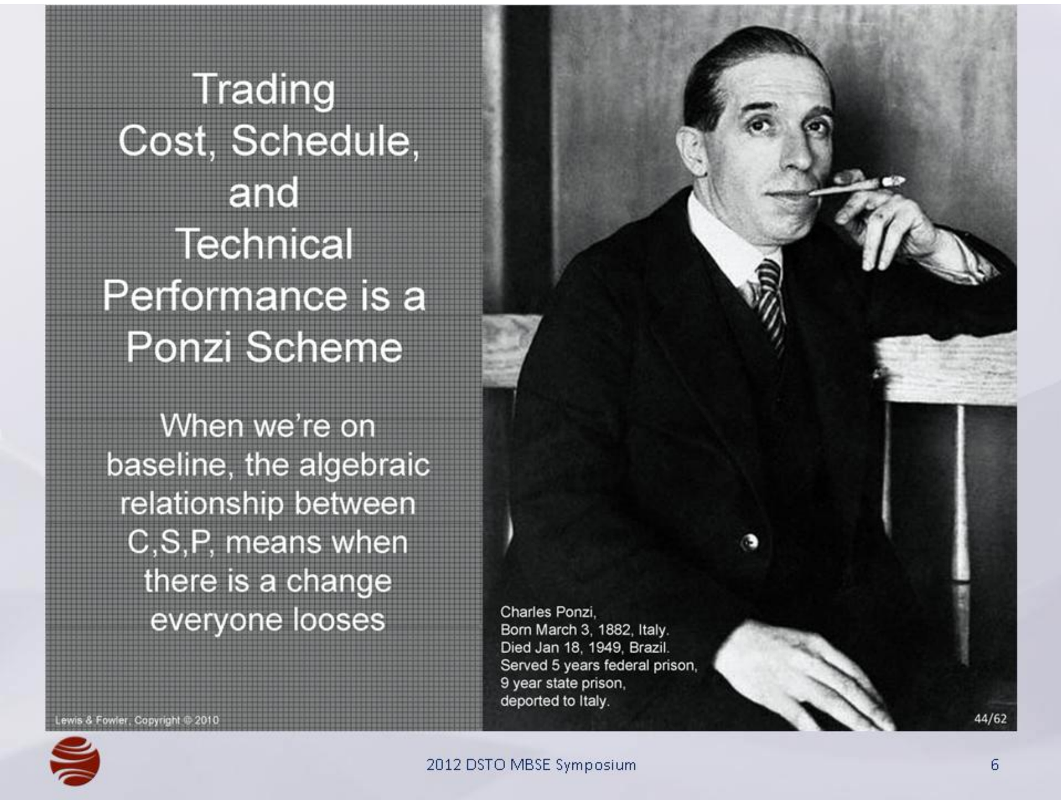
Trading Cost, Schedule, and Technical Performance is a Ponzi Scheme
When we're on baseline, the algebraic relationship between C,S,P, means when there is a change everyone looses
Charles Ponzi,
Born March 3, 1882, Italy.
Died Jan 18, 1949, Brazil.
Served 5 years federal prison,
9 year state prison,
deported to Italy.
Lewis & Fowler, Copyright © 2010
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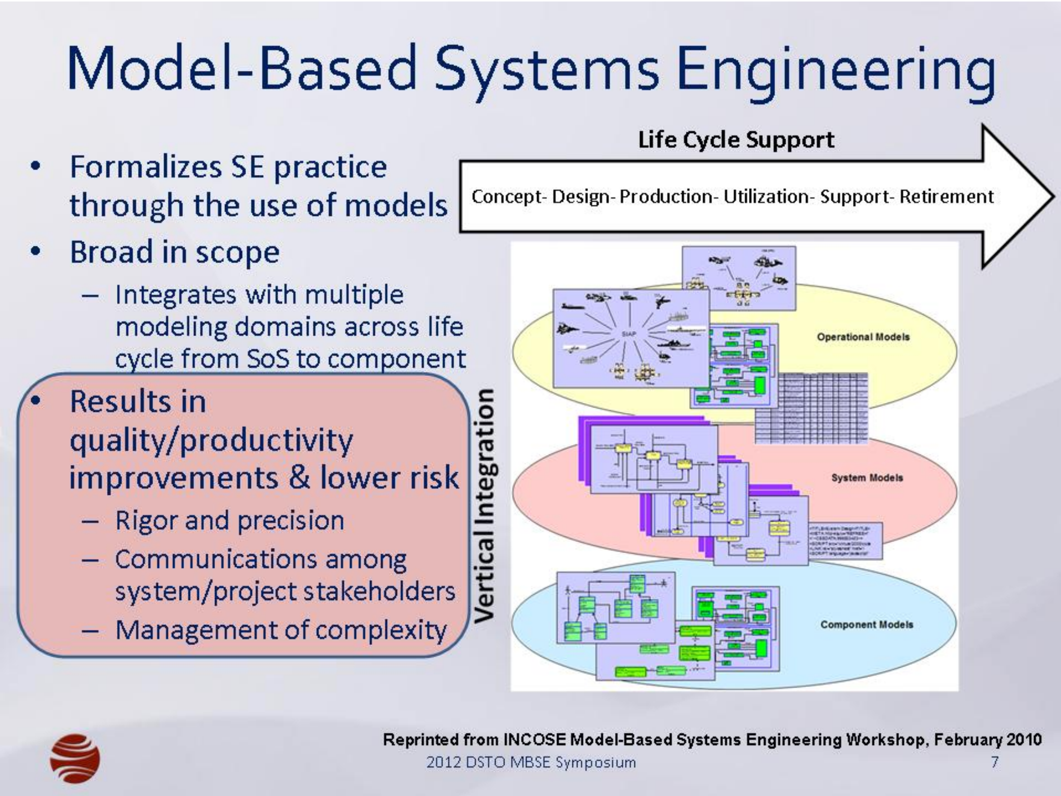
Model-Based Systems Engineering
• Formalizes SE practice through the use of models
• Broad in scope
– Integrates with multiple modeling domains across life cycle from SoS to component
• Results in quality/productivity improvements & lower risk
– Rigor and precision
– Communications among system/project stakeholders
– Management of complexity
Life Cycle Support
Concept- Design- Production- Utilization- Support- Retirement
Vertical Integration
Operational Models
System Models
Component Models
Reprinted from INCOSE Model-Based Systems Engineering Workshop, February 2010
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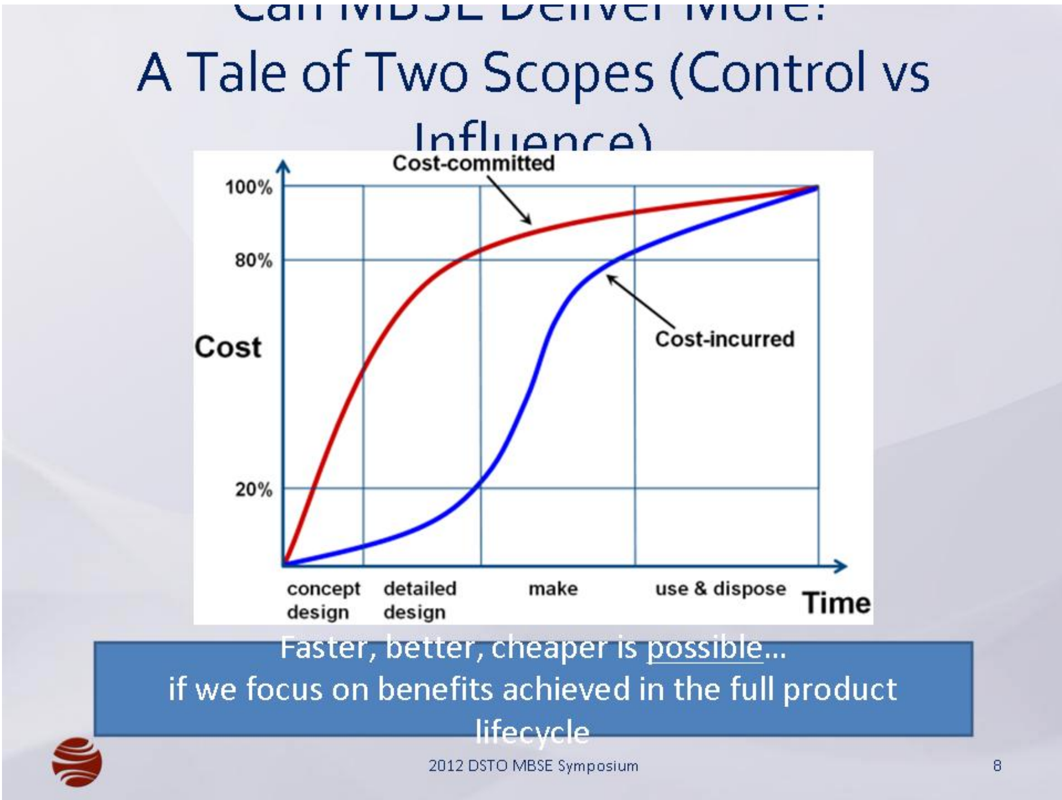
Can MBSE Deliver More:
A Tale of Two Scopes (Control vs
Influence)
Cost-committed
100%
80%
Cost
Cost-incurred
20%
concept
design
detailed
design
make
use & dispose
Time
Faster, better, cheaper is possible…
if we focus on benefits achieved in the full product
lifecycle
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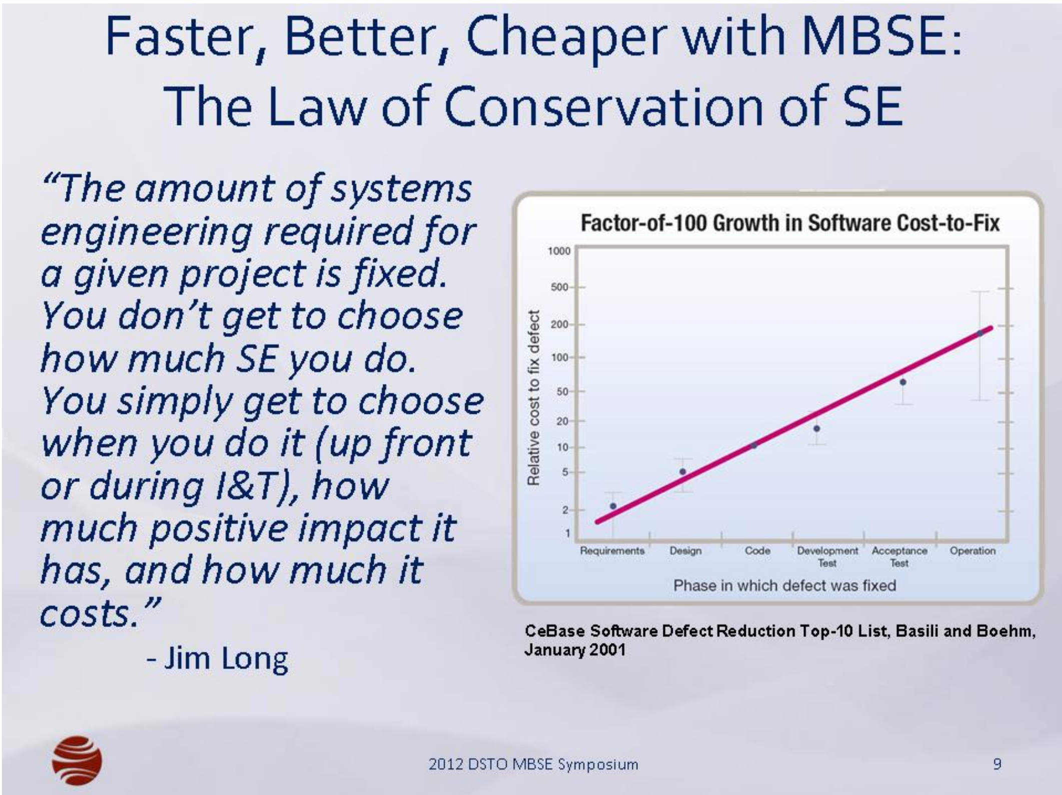
Faster, Better, Cheaper with MBSE:
The Law of Conservation of SE
"The amount of systems engineering required for a given project is fixed. You don't get to choose how much SE you do. You simply get to choose when you do it (up front or during I&T), how much positive impact it has, and how much it costs."
- Jim Long
Factor-of-100 Growth in Software Cost-to-Fix
Relative cost to fix defect
1000
500
200
100
50
20
10
5
2
1
Requirements
Design
Code
Development
Test
Acceptance
Test
Operation
Phase in which defect was fixed
CeBase Software Defect Reduction Top-10 List, Basili and Boehm, January 2001
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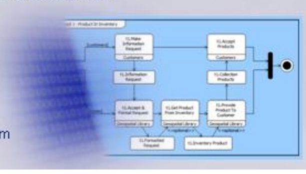
MBSE for Increased Lifecycle Quality

- Early identification of requirements issues
  - Missing requirements, conflicting requirements, and general defects
- Enhanced stakeholder communication to enable better validation
  - "We fail more often because we solve the wrong problem than because we get the wrong solution to the right problem." (Ackoff)
- Disciplined (and defensible) basis for decision making
  - Moving beyond "a miracle occurs here" analysis
- Enhanced visibility into information gaps and system design integrity
  - Model-driven consistency vs document-based hope
- Improved specification of allocated requirements to HW/SW
- Reduction in design errors reaching integration & test
- Rigorous traceability from need through solution

vs



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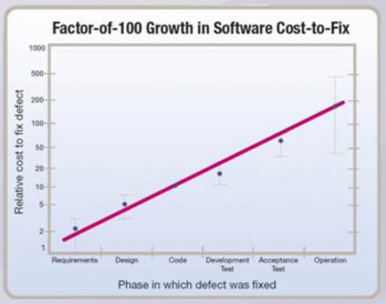
MBSE for Reduced Lifecycle Cost

- Earlier error detection and reduced rework
- Early/on-going requirements validation and design verification
- Reduced cost of integration & test
- Reuse across divergent products
- Identification and adoption of system patterns and heuristics
- Improved cost estimates
  - Insight is often as important as reduction
- Reduced cost overruns through higher lifecycle quality



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MBSE for Accelerated Capability Delivery

- Enhanced individual command of the problem and solution
  - Opportunity to work at "thinkspeed" rather than document index speed
- Improved alignment of collective team understanding
  - One high-visibility version of truth
- Reduction of rework
- Reuse of models to support design/technology evolution
- Streamlined integration & test through fewer errors
- Simplified problem resolution (and expanded options) through early detection
- Improved impact analysis of requirements changes
- Knowing when you are done!
- Reduced schedule overruns through higher lifecycle quality

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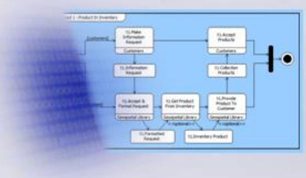
MBSE for Happier Customers

- Enhanced agility, adaptability, and responsiveness to change
- Improved communication & insight
- Increased confidence through argumentation and command of the problem and solution

vs



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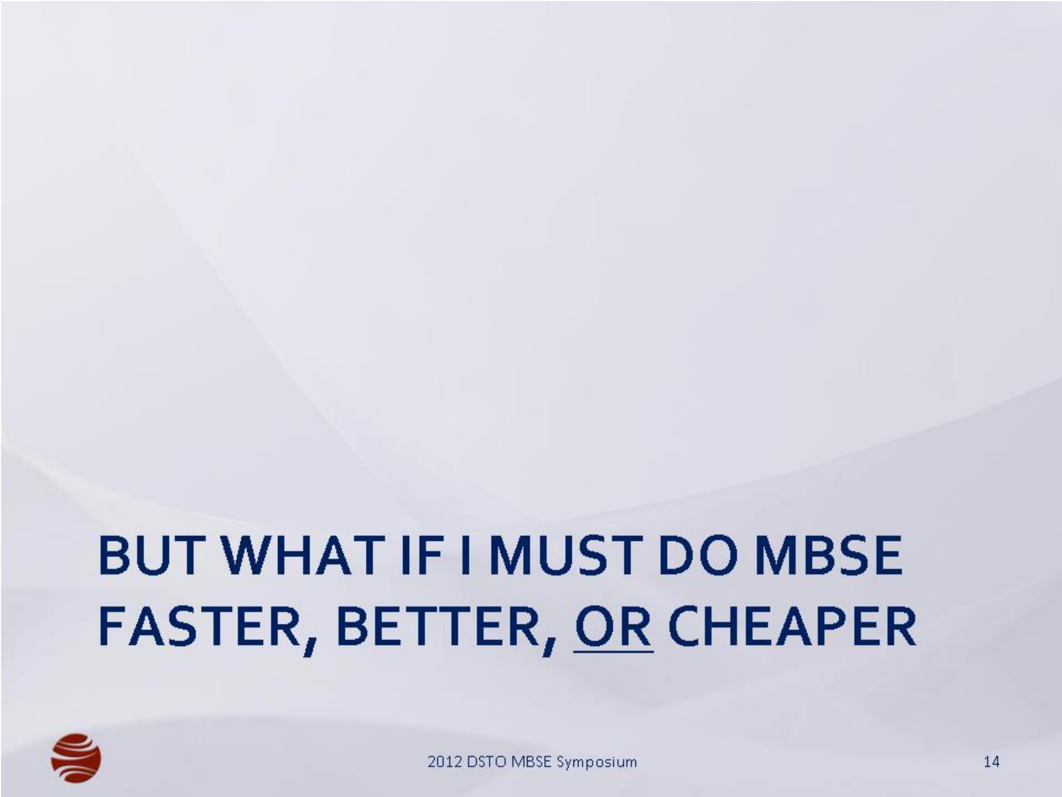
BUT WHAT IF I MUST DO MBSE FASTER, BETTER, OR CHEAPER
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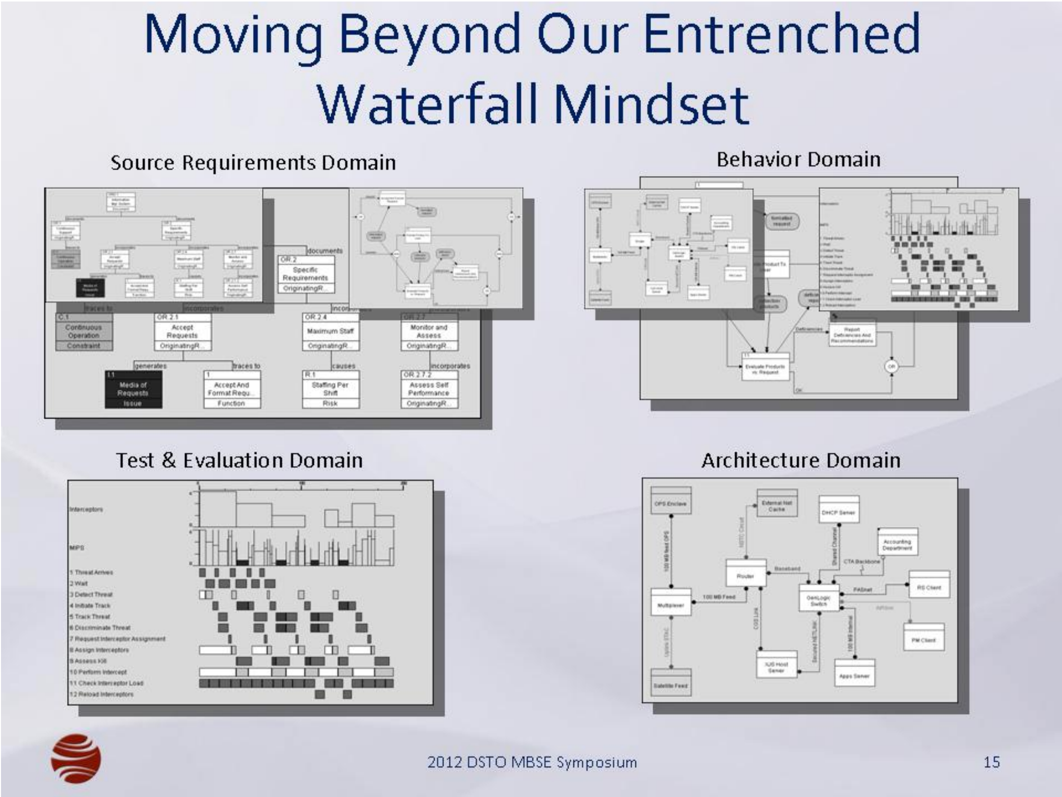
Moving Beyond Our Entrenched Waterfall Mindset
Source Requirements Domain
Behavior Domain
Test & Evaluation Domain
Architecture Domain
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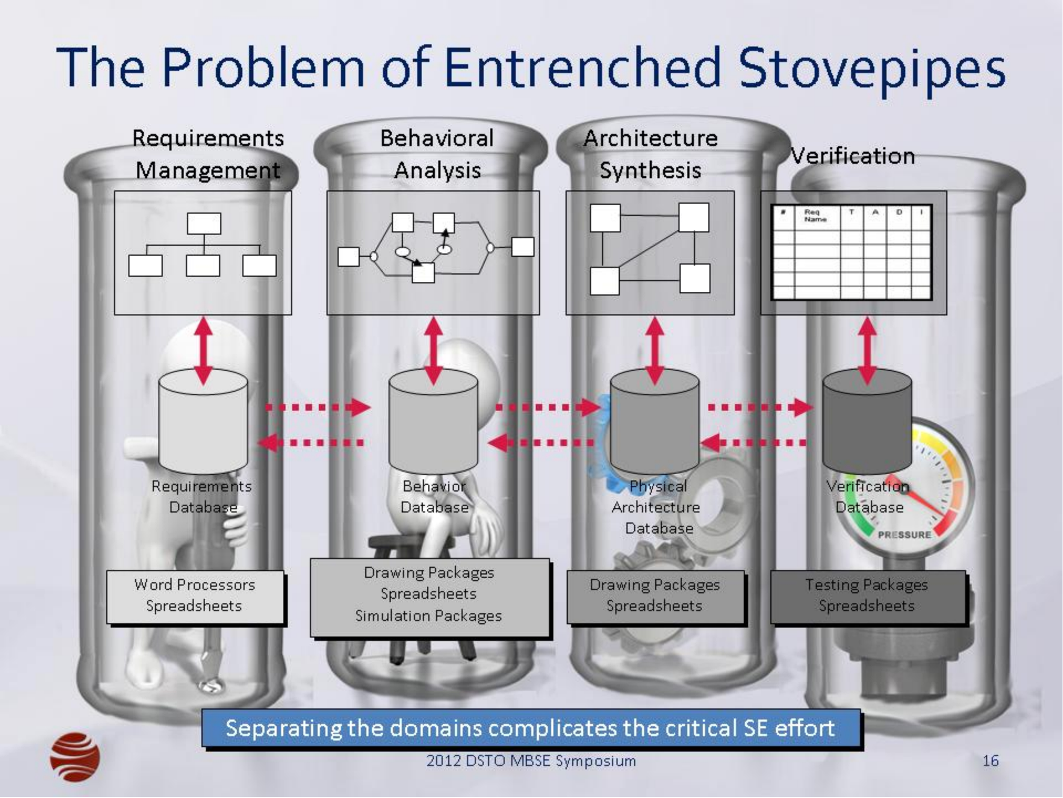
The Problem of Entrenched Stovepipes
Requirements Management
Behavioral Analysis
Architecture Synthesis
Verification
Requirements Database
Behavior Database
Physical Architecture Database
Verification Database
PRESSURE
Word Processors Spreadsheets
Drawing Packages Spreadsheets Simulation Packages
Drawing Packages Spreadsheets
Testing Packages Spreadsheets
Separating the domains complicates the critical SE effort
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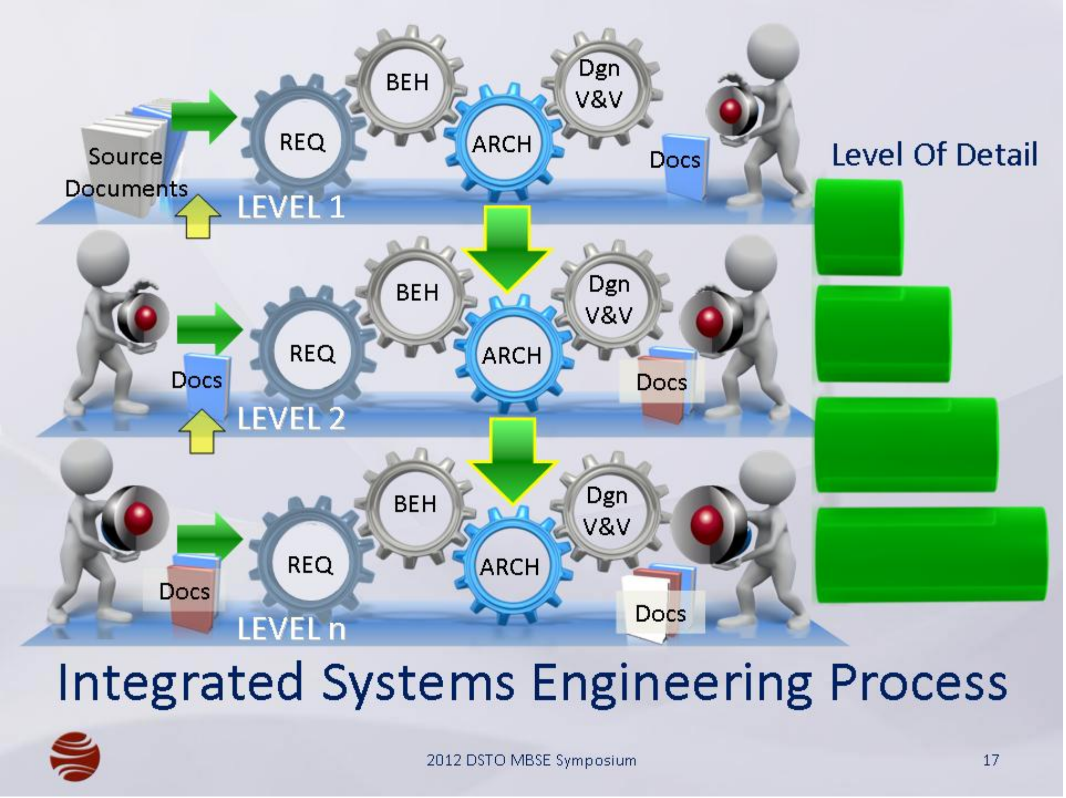
Source Documents
REQ
BEH
ARCH
Dgn V&V
Docs
Level Of Detail
LEVEL 1
LEVEL 2
LEVEL n
Integrated Systems Engineering Process
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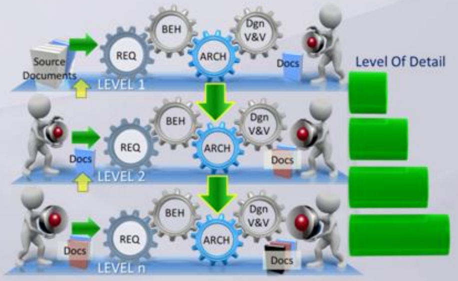
Optimizing MBSE for Quality

- Defend the existing SE schedule and budget
- Invest in the tools, training, and experience appropriate for your project
- Enjoy the SE and lifecycle benefits listed previously
- Maximize project degrees of freedom as you apply the MBSE approach
  - MBSE technology adoption
  - Exploration of alternatives
  - Analysis through executable models
  - Reduction of risk
  - …



The scenario we hope for!

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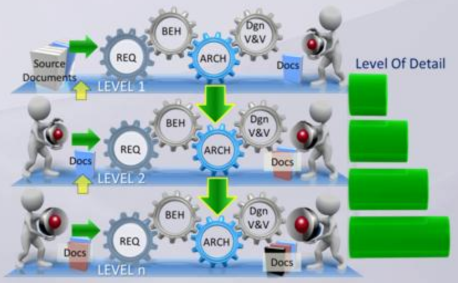
Optimizing MBSE for Schedule and/or Budget

- Realize inherent savings from MBSE transformation
  - Reduced (eliminated) specification production costs
  - Reduced cost of change request / impact analysis
  - Enhanced team productivity
  - Enhanced team comprehension by eliminating the “plague of vague”
  - Enhanced process efficiency and effectiveness
- Reduce team size
- Ask “who” questions rather than “what” / “how” questions
  - Who has done this before such that I can reuse models or patterns?
- Sacrifice level of detail, not quality, consistency, or completeness



The scenario we will eventually face

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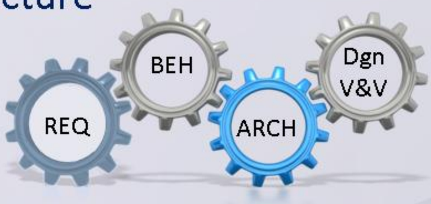
Faster, Better Cheaper is Possible: An Integrated, MBSE Approach

- Provides discipline and structure
- Enhances communication
- Increases quality
- Reduces risk
- Ensures convergence through layered approach
- Speeds delivery and enhances agility, especially in the face of change
- Accelerates (radically) the exploration of revisions, alternatives, and variants



Beware the trap! These benefits are possible through model-based SE but not diagram-centric SE.

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Selling the Benefits of Model-Based Systems Engineering

- Realize that faster, better, cheaper is possible
  - But understand the “silver bullet syndrome”
- Focus first on lifecycle value
- Argue by analogy
  - “Would we perform CAD or integrated circuit design by hand?”
- Move the conversation from price/cost to value and ROI
- Sell technologies only to technologists
- Avoid telling all that you know
  - The curse of the engineer
- Don’t underestimate the costs of transformation training, and experience)

Under-promise and over-deliver to maximize the likelihood of success for you, your project, and our practice

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For Additional Information
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4. Lessons Learned in Introducing MBSE: 2009 to 2012

A. Peter Campbell
University of South Australia

Abstract

An overview of the lessons that are emerging from recent efforts to employ MBSE in the development of large complex projects in both the defence and civilian sectors. A broad interpretation of MBSE will be taken to encompass tool systems that embody the spirit of MBSE, if not the specific modern practice arising from the OMG/INCOSE sources. The paper will address findings on lessons learned with respect to process development, cultural resistance, management perception and training methods and needs.

Presenter Biography

A. Peter Campbell returned to Australia from 22 years in the US in late 2000. He worked on three year contract (2004-07) for CSIRO Complex Systems Science Initiative to introduce complex system simulation tools for agricultural landscape planning and critical infrastructure analysis. In May 2004, Peter joined the Systems Engineering and Evaluation Centre (SEEC) at the University of South Australia as Professor of Systems Modelling and Simulation, working on the application of complex adaptive system simulation technology to large scale system integration projects at UniSA. Recent research includes architecture design for model based systems engineering applications to support evolvable systems integration management and the development of software agents to replace humans in the loop in defence T&E environments.

Now in Defence and Systems Institute (DASI) at UniSA Peter has the responsibility for business development of modelling and simulation, particularly in the defence area. October 2010 joined University of Wollongong as Professor of Infrastructure Modelling in the SMART Infrastructure Facility while continuing at UniSA. Work is in the area of the application of ABM and MBSE to the improvement of the management of large infrastructure development projects, with a specific project to develop an ABM of the interaction between transportation needs and changing demographics in metropolitan Sydney.

Prior to 2000 Peter worked at Argonne National Laboratory in US for 15 years where he was involved in the development of advanced agent based modeling methods with application to decision support tools for defence and industry applications. Project lead and designer for ABM tools for energy supply, drug interdiction, hospital work flow, logistics operations and a range of defence applications

Presentation

Lessons Learned in Introducing MBSE -2009 to 2012

By

A. P. Campbell

UniSA, Nov. 2012

Introduction

- This presentation is based on a survey done for DSITA in late 2012
- Several themes became apparent
  - Huge amount of work going on globally at the SOS level and organisational modelling
  - Further tool development, and especially the production of domain specific templates and profiles make things a bit easier
  - Still a dearth of specific ROI numbers

Older Lessons - 1

- Organisational cultural change is generally needed – so there needs to be specific effort made to do this
- Upper management support is essential – upfront costs, for tools, training, infrastructure, schedule
- There remains a dearth of expertise, so early work needs to be planned for this constraint
- Frequent – daily – interactions are needed to ensure processes remain coherent at the beginning of project
- The models must continue to evolve – model maintenance is often neglected because it is seen as expensive – also requires some organisational change

Some Sources -1

- Some of the important sources emphasising the need for addressing cultural change and obtaining management support:
  - Rolls-Royce
  - NASA/JPL
  - UK MOD
  - EELT
  - Crescendo – EADS and ~ 50 others
  - NDIA !

Older Lessons - 2

- Real examples are needed to convince others of the benefits
- It is hard to do – just do it, but on a small scale first
- Some of the benefits are:
  - Reduced time to completion
  - Earlier risk identification
  - Reduced rework
  - Better prospects for re-use

Older Lessons - 3

- Benefits (continued)
  - Enhanced interoperability
  - Captures lifecycle information for future upgrades
  - Improved reliability
  - Models have more to contribute than just supplying quantitative analysis – they improve capture and description of design and are powerful first steps, immediately improve communication and understanding ("The benefits of this would be difficult to overstate" JPL)

Newer Lessons - 1

- There are psychological reasons why it is hard as well as cultural ones. ("The human mind wants positive progress. In engineering this is seen in the tendency to prioritize developing solutions, and working the first feasible idea - an illusion of progress. We must recognise that this is natural human behaviour, and take explicit steps to avoid it." Beasley 2012)
- Organisational structure change to remove stove piped responsibilities
- Leverage learning with synergistic work – related to "just do it"?

Some Sources -2

- Correct structuring of projects is necessary to ensure maximum benefit for use of MBSE
  - NDIA
  - EELT
  - Aster S.p.A
  - SOS – several of the presentations at TTCP JSA TP4, 2012

Newer Lessons - 2

- Suggested team organisation for a large project – 3 tiers: (From JPL Europa study)
  - Small core of ~ 6 modellers – but don't isolate it
  - Larger group of ~ 20 modelling savvy engineers – where the top level expertise resides, such as the system architect
  - The rest of the project personnel
- Pay attention to the level of detail that modelling is taken to – duality OK in large project as long as consistent at top level
- Useful for supporting virtual integration

Newer Lessons - 3

- Helps to overcome the human tendency to read what we think text says, rather than what it actually says
- Keep model and analysis separate – enables model re-use on later analyses of different options
- Usefulness of "socialising", managing staff rotation in long running projects, need for total involvement of all team members

Some Sources -3

- NASA/JPL – space networks project
- WSAF
- SOS – several of the presentations at TTCP JSA TP4, 2012
- Renault

Major Program Applications

- CRESCENDO (Realisation system and Intervention system) EADS et al (and VIVACE)
- SWTFS (Submarine Warfare Federated Tactical System) 13% savings in SE work, 25% reduction in capability dev't work and 10% quicker than using DOORS in baseline management
- EELT

Project Level Applications/Studies

- Europa project (JPL, Bayer)
- Gripen (SAAB, Herzog)
- SysML vs Siemens Team Centre (Boeing, Gau)
- A PLM system for auto manufacture (Ciriello)
- Another comparison study (BAE, Wilber)
- MBSE savings (Raytheon, Saunders)
- Manufacturing System design (GIT, Batarseh)
- Requirements for defence systems (ASTER, Petrinca)
- US FAA NextGen

LMCo JSF Modelling

The Lockheed Martin Simulation and Systems Integration

Laboratories Ft. Worth Texas

- Not much to do with MBSE as we are talking about it here, but I want to tell you about it anyway –"Virtual to real"
  - 29 Simulation labs for F16, F22, F35, plus a complete system flying in a 737 plus another complete system in an F35 body on special mount on top of one of the buildings
  - Flight Control System, VTL system, Mission system, 6 DoF simulator, even a PC version to introduce FCS system, etc
  - Stove piped until very late 1990s – DOD 5000 series standards required huge amount of work to integrate
  - Would have been much quicker and cheaper if they had been able to use todays tools

Major SOS Research and Programs

- DANSE - Designing for Adaptability and evolutioN in System of systems Engineering – EU FP7
- SAVI – System Architecture Virtual Integration. International effort through the Aerospace Vehicle Systems Institute -2006-2016 (Standard data storage and exchange constructs enable early virtual integration of models distributed across the supply chain. A monolithic solution is not practicable.)
- Architecture framework for the Renault System and Safety data-model
- US DOD Implementations and Initiatives – briefly shown on next 5 slides: ERS, CREATE, AVM, FACT, DISA

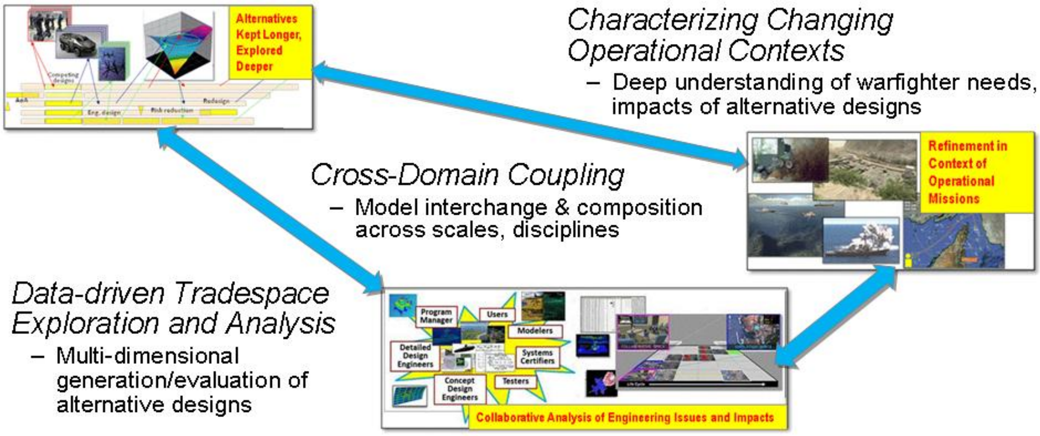
MBSA as a Foundation for Engineered Resilient Systems

Systems Representation and Modeling
- Physical, logical structure, behavior, interactions, interoperability…

Characterizing Changing Operational Contexts
- Deep understanding of warfighter needs, impacts of alternative designs

Cross-Domain Coupling
- Model interchange & composition across scales, disciplines

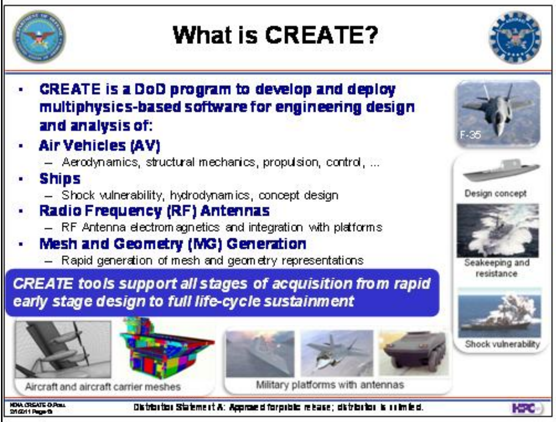
Data-driven Tradespace Exploration and Analysis
- Multi-dimensional generation/evaluation of alternative designs

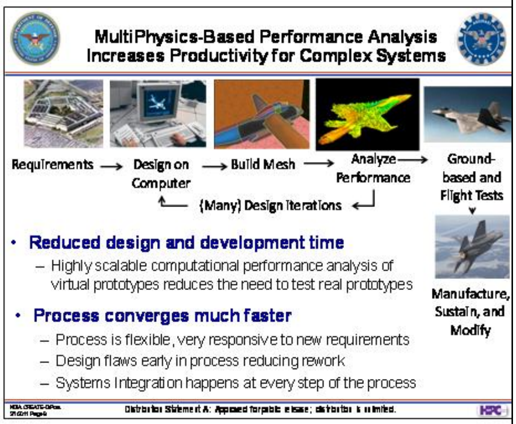


Collaborative Design and Decision Support
- Enabling well-informed, low-overhead discussion, analysis, and assessment among engineers and decision-makers

Computational Research and Engineering Acquisition Tools and Environments (CREATE)

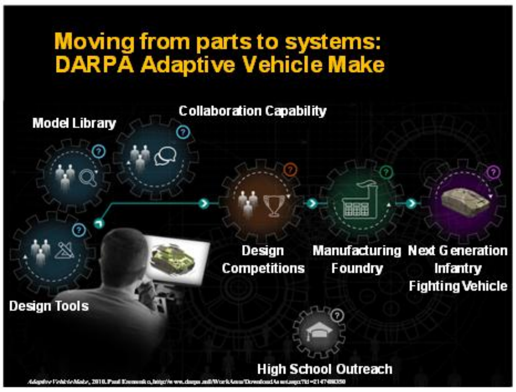
- Enable major improvements in DoD acquisition engineering design and analysis processes, by developing and deploying scalable physics-based computation engineering software products

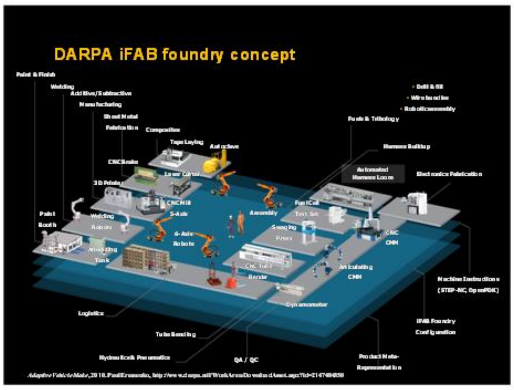




MBE: Adaptive Vehicle Make (AVM)

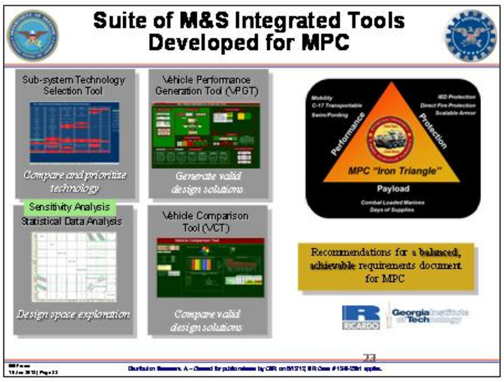
- DARPA program to address the technical problem at the 'seams' – between stages of production, between components, and between organizations. 3 major parts: Shorten development times for complex defense systems; Shift product value chain toward hi-value designs: Democratized design

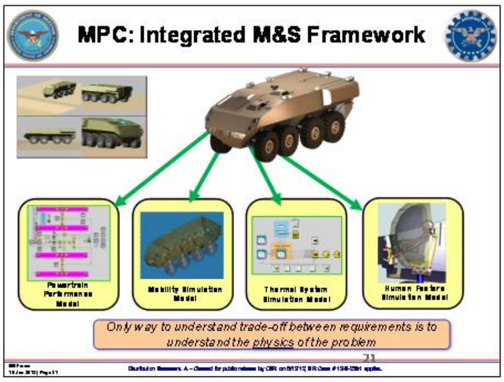




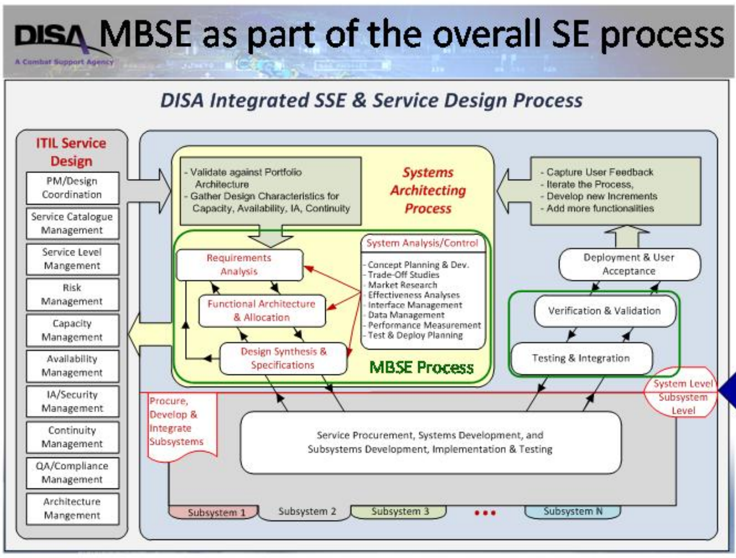
MBE: Framework for Assessing Cost and Technology (FACT)

- A USMC M&S Systems Engineering process enabling rapid trade space and alternative analysis by simultaneously exploring the trade space between cost, schedule, performance and risk





MBSE as Framework for Overall DISA SE Process



- Use as the model and environment to support their role as enterprise engineering for common services in the DoD IT infrastructure
- Provides a common framework ('Systems level') for diverse and distributed ('Sub-systems level') design and engineering activities

Tools

- Kalawsky et al (2012 unpublished) Model based system design and HIL simulation for system verification with model transformation tools to facilitate bi-directional transformation of a Rhapsody model to a Simulink model
- Tool set for developing Aviation Safety-Critical Runtime with Ability to Certify to Do-178B Level A - Atego
- Dassault Catia, Siemens NX – fully integrated PLMs
- OMG Model Interchange Working Group

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5. Theatre of Operations: An entertaining problem

Tommie Liddy[1], Michael Waite[1], Paul Logan[2] and David Harvey[1]
[1]Aerospace Concepts and [2]Empel Solutions

Abstract

System requirements and constraints specify how a system must look, feel and function; but it is the needs of the users and stakeholders that give the system its raison d'etre. If a valid solution system is to be delivered, the end-users' needs must be correctly identified, within the stakeholders' constraints. While this process forms an essential part of the concept phase of the engineering lifecycle, it is often left under-done, with needs attributed to the general, non-specific "user". Since needs vary per user, it is of critical importance to identify who the end-users are, what their role in the operational behaviour of the system entails, and from where they came. Similarly, when considering stakeholder constraints it is necessary to identify who the stakeholders are, what their influence on the system entails, and from where they view the system.

One of the more significant changes to the US Department of Defense Architecture Framework (DoDAF) from version 1.5 to 2.0 is the manner in which operational entities are considered. In version 2.0, 'Performers' were added to the DoDAF meta-model to capture those entities responsible for performing the representative activities which make up the operational scenarios. These Performers replaced the often over-used and poorly-understood 'Operational Nodes'.

Additionally, capability stakeholders offer requirements, in the form of constraints, which bound the problem space. These constraints, in combination with the user needs, allow the systems engineer to understand the operational concept of the capability. User needs and other stakeholder requirements are identified and described from the perspective of a particular class of stakeholder. To address these perspectives, each stakeholder-class and their environment is modelled with emphasis on identifying what they need the system of interest to be or not to be - i.e. what they need to achieve (goals and objectives), and to what they need to conform (limitations and constraints). The aggregate model of all stakeholders is thus an integrated architecture description of the problem space (ISO42010 2008).

Effective needs analysis requires complete understanding of the users and how they act as operational performers, their roles, and the organisations to which they belong. This presentation provides an entertaining yet rigorous example and uses colloquial language to describe in readily understood terms a robust needs analysis methodology that is effective, efficient and also compliant with the Defence Architecture Framework (DAF). The example demonstrates the application of a model-based approach to concept engineering and, in particular, how a better understanding the 'performers' leads to a solid basis on which to design a solution.

Presenter Biographies

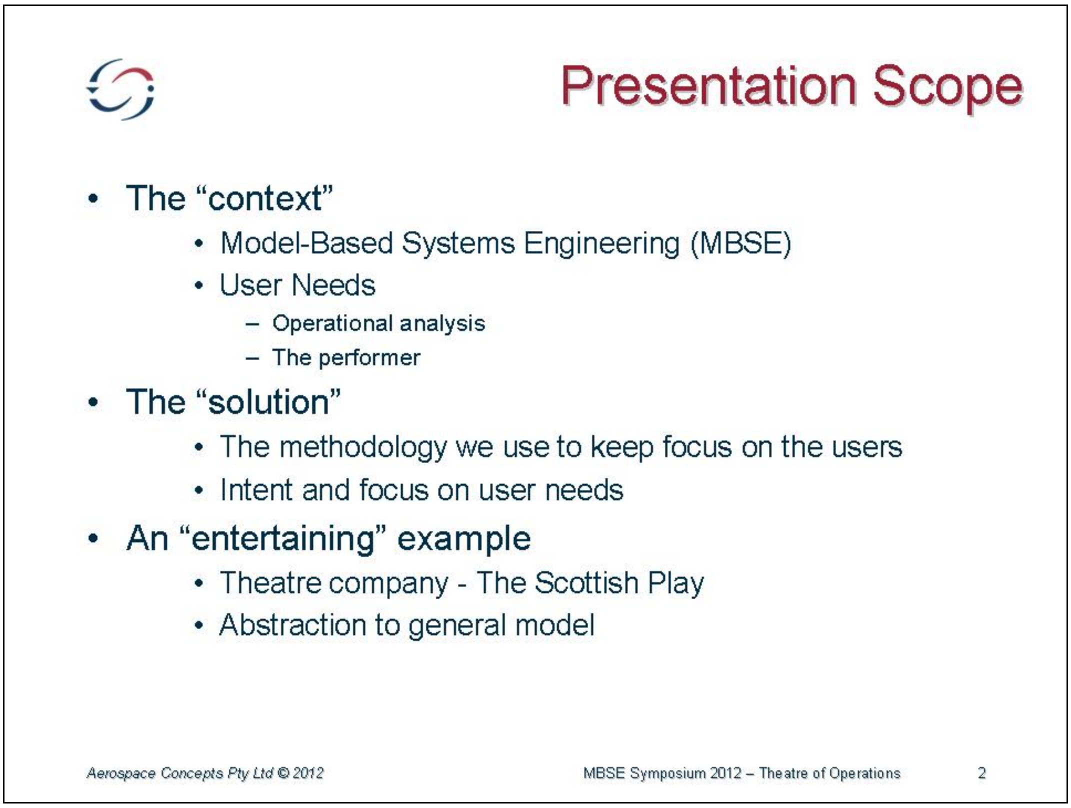
Tommie Liddy is a mechatronic engineer completing his Ph.D. in Robotics at the University of Adelaide while working as part of the Model-Based Systems Engineering (MBSE) team at Aerospace Concepts. His academic study has focused on navigation control for Ackermann vehicles and uses vector fields as control schemes. Development of this work was achieved through simulation of vital concepts then a physical implementation of the final system. As part of the MBSE team at Aerospace Concepts Tommie is developing MBSE tools for operational analysis and capability definition.

Michael Waite has been working as a professional engineer for over ten years since completing his Bachelor of Engineering (Mechatronics) degree in 2001. His career has seen him working for several multi-national automotive companies in Australia, Asia and Europe, including Mitsubishi Motors, Ford and Caterpillar. He currently works for Aerospace Concepts, a systems engineering consulting company, specialising in the development of complex-system capabilities.

Paul Logan, following a twenty-three career in the Australian Army, has acquired twenty years of experience with model-based systems engineering methods, techniques and tools. He introduced MBSE into the Jindalee Operational Radar Network project in 1991 and has since applied model-based analysis and design in commercial and military projects. From 2002 Paul has been involved in Capability Definition Document (CDD) development for the Defence Department. Paul is a certified instructor of Vitech Corporation's introductory and advanced courses on Model Based Systems Engineering using CORE®. Paul holds Bachelor of Engineering (Communications) and Master of Information Science degrees. He is a member of INCOSE, IEEE and SESA, of which he is a former President.

Dr David Harvey is a systems engineer with a particular interest in Model-Based Systems Engineering. He holds a bachelor degree and a doctorate, both in the field of mechatronics. He currently leads the Model-Based Systems Engineering (MBSE) program at Aerospace Concepts Pty Ltd. This team is developing an MBSE approach and tailored tool to assist in complex system definition in conjunction with Australian Defence partners. As well as this development, he is also involved in applying the tool and approach to capability definition in major Australian Defence projects.

Presentation



What is MBSE

- What is Systems Engineering?
  - Systems engineering involves taking a **structured approach** to definition, design and implementation of systems that address defined **user** problems
- What pushes us towards Model-Based?
  - Outsourcing (Sparrow & Wegner 2011)
    - Recording systems knowledge, while retaining the understanding of how to find it
  - **Increasing complexity of projects vs understanding capacity** (Metcalfe's Law vs Miller's 'Magical Number')
  - Teams of Systems Engineers

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Where do we use MBSE

MBSE can aid in defining needs and functionality **early in the development cycle** and then proceeding with design synthesis and system validation while considering the **entire systems lifecycle**

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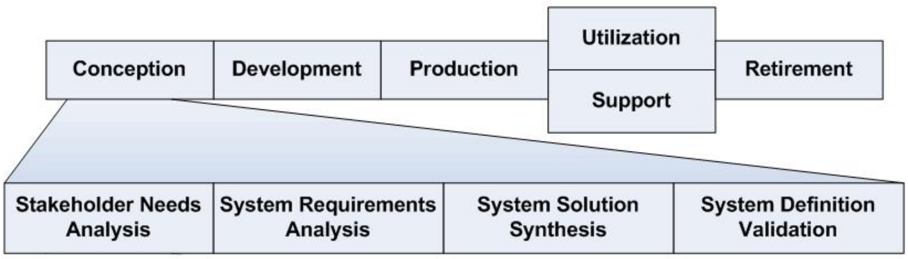
Benefits of MBSE

- Focus on the information of and about the system leads to a number of benefits
  - Traceability
    - Links established and maintained as part of the approach
  - Consistency
    - 'Single source of truth'
  - Adaptability
    - Any number of views or documents can be produced as snapshots of slices of the model
  - Robustness & information sharing
    - System information made explicitly clear
    - Domain specialist views are possible – without neglecting the interconnected nature of domains

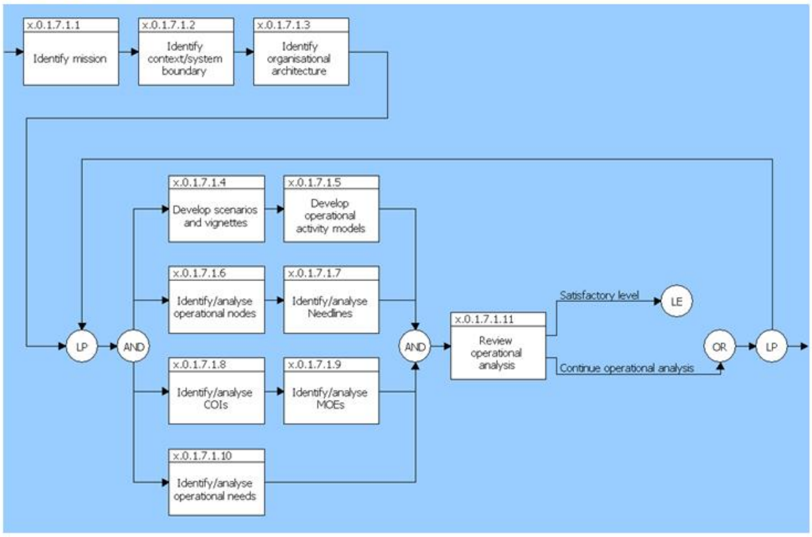
MBSE in the Conception Phase

- Conception phase
  - Needs analysis
  - Requirements analysis



MBSE in the Conception Phase

- A detailed look at the conceptual phase, this is how we gather the User's needs



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User Needs

When **MBSE** is applied to capability definition we are able to help people **Ask** for what they **Need**, not just what they **Want**, ensuring the **User** is **King**

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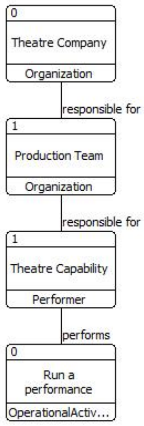
An Entertaining Example

- The CONOPS: A travelling theatre company, putting on “The Scottish play” in a new town.
  - There is a Theatre Company (the Organisation)
  - Who, when mobilised to put on a performance, are given roles to play
  - It has Actors, Crew and Management (the “Performers”)
  - And activities to perform (Scenarios and Vignettes)

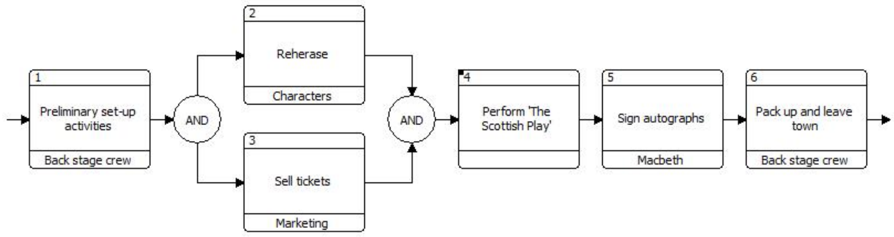


The Scottish Play

Theatre Company Organisation	Roles in The Scottish Play	The Performers
Cast	Principal Actor	Macbeth Lady Macbeth
	Support Actor	Macduff Duncan Banquo Banquo’s ghost Angus Ross Witches three Others…
Crew	Back Stage Crew	Stage Hand Lighting guy Sound guy Wardrobe Stage manager
Production	Management	Producer Director Marketing Playwright

The Scottish Play

- Our "Campaign" involves the theatre company putting on a performance
  - Note: that this is a simplified model for use in this example, and is therefore not intended to be complete
- Each activity is decomposed down until the activity is performed by a single Performer (i.e. a user class)



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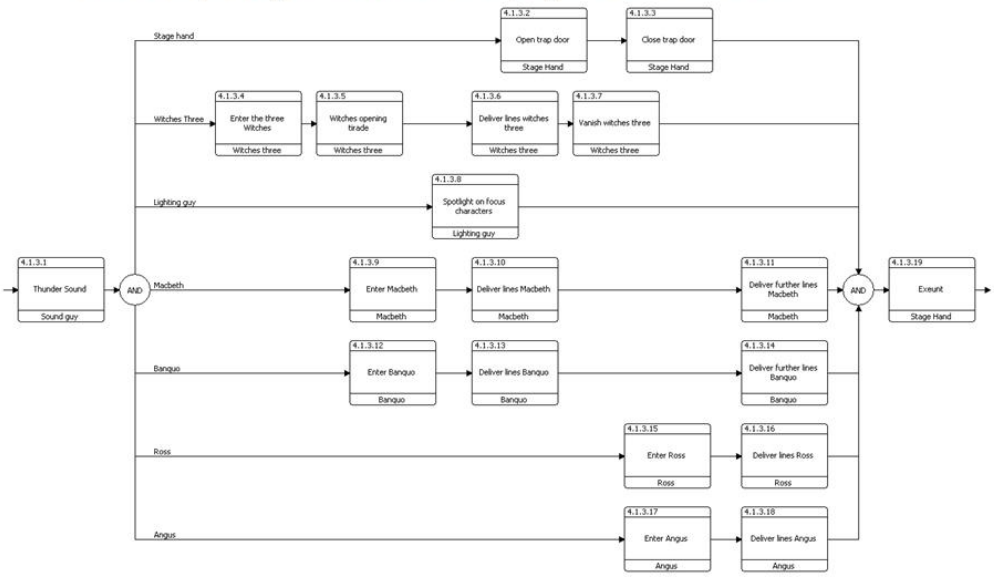
Thunder. Enter the Three Witches

- An example Vignette in our Campaign…Act I Scene III



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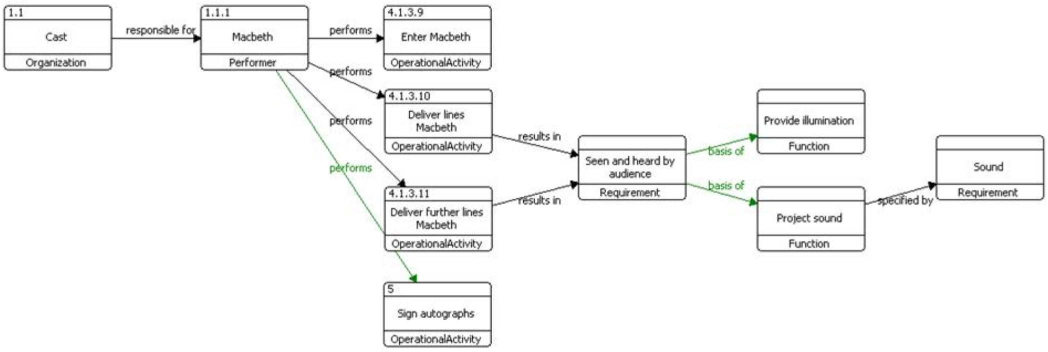
Following a Thread

- The user **Macbeth**
  - A member of the **Cast**, in the principal actor role, becomes the performer **Macbeth**
  - **Macbeth** performs activities in Act I Scene III, such as **Delivering Lines**, and these result in **User Needs**



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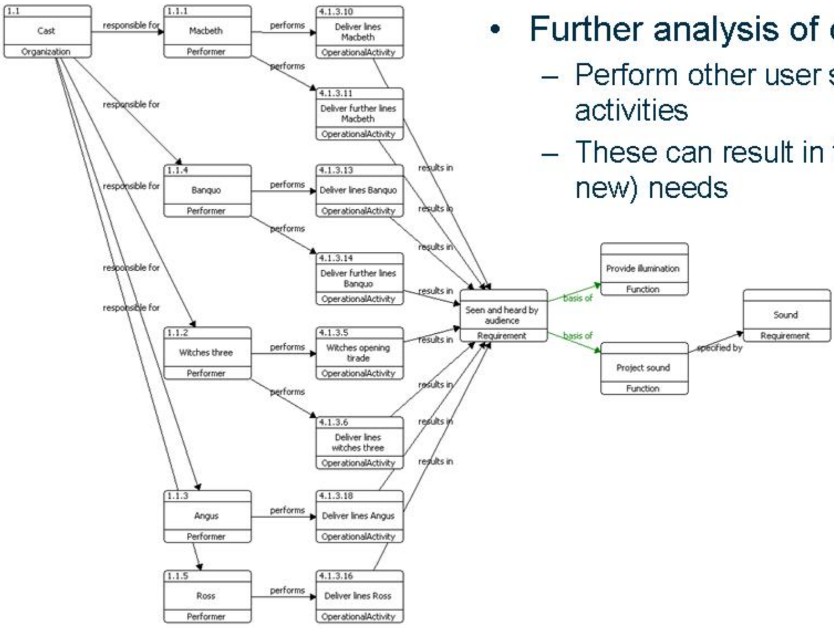
Following Many Threads

- Further analysis of other users
  - Perform other user specific activities
  - These can result in the same (or new) needs



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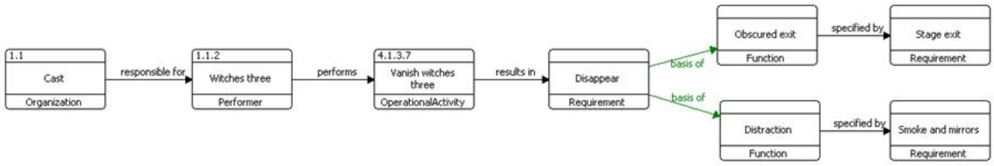
Grouping Users

- The Witches Three
  - The three witches are aggregated up to be a single Performer
  - This decision is based on the level of detail in the Activity Model and the commonality of the Performers
  - We want to keep the knowledge model as simple as possible to elicit all the user needs, but no simpler



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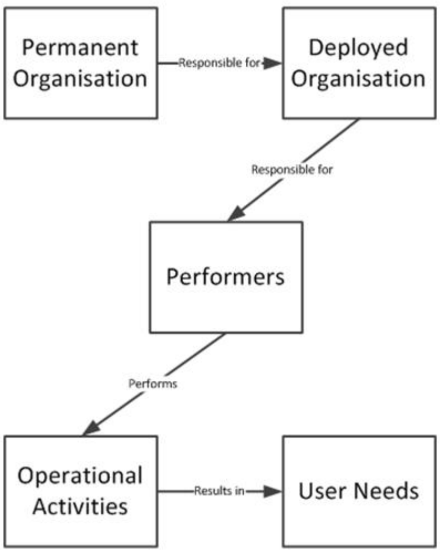
General Model Architecture



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Conclusion

- MBSE can aid in defining needs and functionality early in the development cycle
- By applying analysis and rigor to the development of a set of Users, or User classes, we can develop a concise yet complete set of user needs
- Just as one user can have many needs, many users can have a shared need
- The person developing the user needs should have a good understanding of the user, and interact with them where possible, to enable user interests to be appropriately defined

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Take Home Message

User needs and other stakeholder requirements should be **identified** and described from the perspective of **each** class of **stakeholder**

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AEROSPACE CONCEPTS

So, thanks to all at once and to each one

Questions?

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6. Using MBSE to Understand the Link between Capability Acquisition Projects and DSTO Technology Advice

Simon Demeduik[1], Wayne Power[2] and Brett Morris[1]
[1]Maritime Platforms Division, DSTO and [2]Weapons Systems Division, DSTO

Abstract

One role performed by technology Groups within DSTO is the provision of whole of platform advice to Defence capability acquisition projects during the needs and requirements phases of the capability development lifecycle. At present the process, or system, that links the request for advice from a capability acquisition project stakeholder to the analysis and advice provided by DSTO, is not clearly understood or defined. This lack of clarity can influence the form and content of the advice provided by permitting misinterpretation of the intended purpose of the advice by the DSTO Groups and/or misunderstanding on the part of the capability stakeholders as to the type of analysis required and the expected bounds of validity of the advice. The role that DSTO provides to the greater Defence organisation is analogous to many customer / service provider relationships in industry, thus this lack of clarity between customer requirements and technical advice provided is broadly applicable.

In order to gain a better appreciation of the process of linking requests for advice to analysis, two main aspects need to be considered, one that resides at the Group level and the other at the enterprise level. The enterprise level considers the wider provision of advice to Defence acquisition projects by DSTO. At this level, the problem is ill-structured and contains a multitude of stakeholders. A soft systems approach is one method that could be beneficial in enhancing our understanding and helping to define the system at this level. This presentation, however, focuses on the Group level. At this level, the problem is somewhat simplified due to the reduction in stakeholders, processes, analysis tools and techniques, nonetheless, the problem space is still non-trivial. It is anticipated that by defining the system at the Group level, a more informed subsequent exploration of the enterprise level could be conducted.

To address the problem at the Group level, a systems engineering approach has been deemed as suitable. This is based on the authors' contention that the problem at hand (i.e. the provision of advice due to a request) can be described as being an assemblage of elements, in the form of related activities and processes that form a unitary whole, where this unitary whole constitutes a system[2]. In this instance, an Object-Oriented Systems Engineering Method (OOSEM) approach[3], along with ISO15288, has been adapted and adopted to the development of a system for providing advice to stakeholders by the appropriate Groups within DSTO.

---

[2] Blanchard, B. S. and Fabrycky, W. J. (2006) *Systems Engineering and Analysis. 4th ed*. New Jersey, Pearson Prentice Hall

[3] 2. Friedenthal, S., Moore, A. and Steiner, R. (2009) *A Practical Guide to SysML: The Systems Modeling Language*. Burlington, MA, Morgan Kaufmann OMG Press

This presentation will cover the exploratory research and concept stages of the development of a system for providing advice and how the DSTO Naval Architecture and Platform System Analysis Group and the Weapons Capability Analysis Group were able to embed MBSE into the activities (for example the user requirements elicitation and analysis) that were conducted. The presentation includes an overview of the user requirements elicitation workshops and their outcomes. Following this, a discussion on some of the common themes arising from the workshops is given. Amalgamation of the outcomes of the workshops to potentially develop a common framework for providing technology advice is discussed. Some of the initial system component feasibility exploration is examined, along with the key lessons learned from embedding MBSE into the system development process. Finally, with the increasing use of Model Based Systems Engineering (MBSE) within Defence capability acquisition projects, the potential for this MBSE approach to be used to develop a linkage between a project's knowledge model and simulation performed within DSTO, will be discussed.

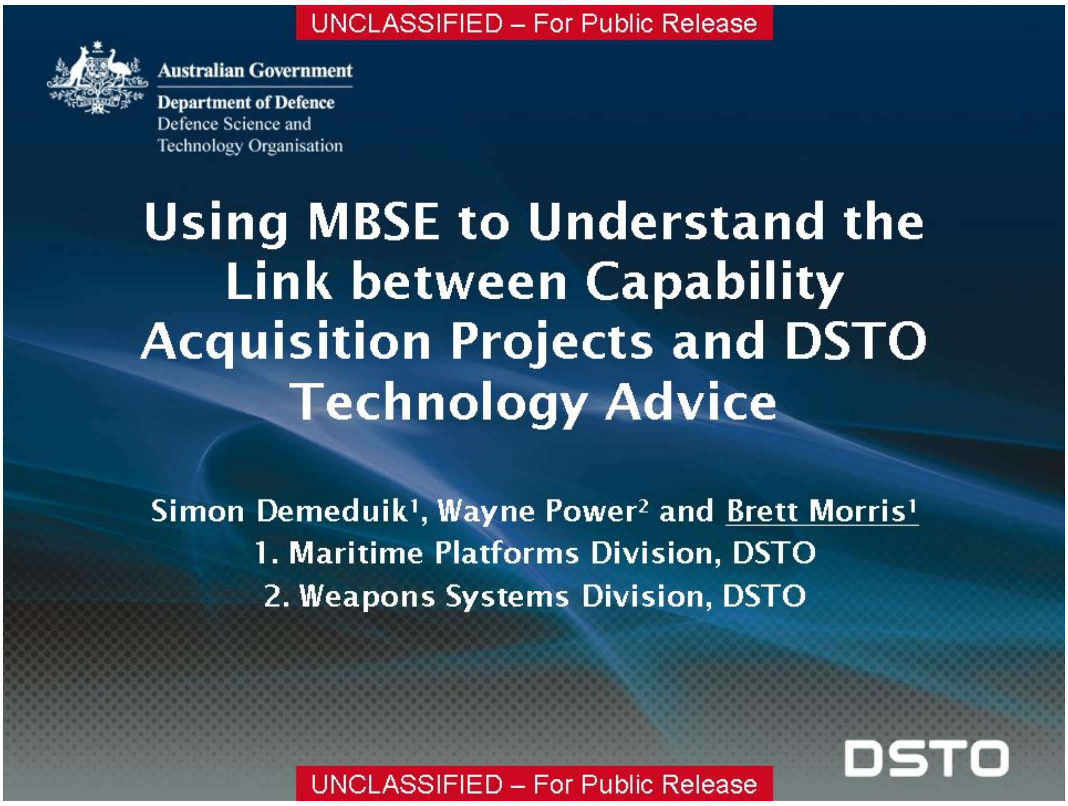
Presenter Biographies

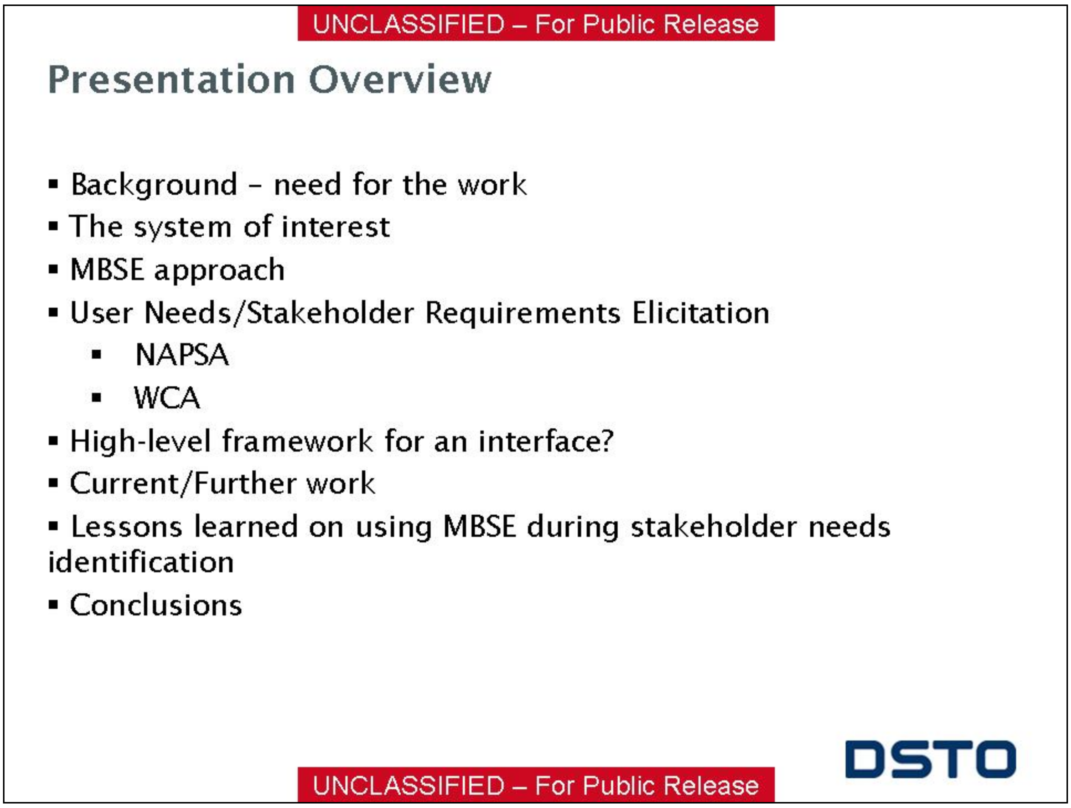
Simon P. Demediuk obtained a Bachelor of Engineering and a Bachelor of Science from Swinburne University in 2009. Since then Simon has worked as a Defence Scientist at DSTO. Simon joined Maritime Platforms Division in 2010 working for the Naval Architecture and Platform Systems Analysis group and currently works on development of analysis tools in relation to the Future Submarine Program.

Wayne Power graduated with honours from the Queensland University of Technology (QUT) with a Bachelor of Engineering (Aerospace Avionics), minor in Systems Engineering. He has spent the last six years working in Weapons Capability Analysis within DSTO's Weapons Systems Division (WSD). His work in WSD has included weapon system integration modelling and analysis, but the major focus of his work has revolved around researching and developing the Whole-of-System Analytical Framework (WSAF). The WSAF employs a Model-Based Systems Engineering approach for the provision of cross-Defence modelling, simulation, analysis and Capability Development activities.

Brett Morris is a Naval Architect/Systems Engineer who joined DSTO in 2007. He has previously worked for the RAN in the Directorate of Navy Platform Systems and is currently working in the fields of Naval ship concept design, structures and hydrodynamics, along with Systems Engineering applications to Naval Architecture. Brett holds a Grad. Dip. In Systems Engineering, a BE (Nav. Arch.) and is currently undertaking part-time research towards a PhD.

Presentation





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Background

- The process linking information request to M&S and advice loosely defined
  - Can lead to:
    - Provision of advice not reflective of request
    - Unrealistic expectations from project
  - Due to:
    - Analysts lacking clarity of purpose
    - Purpose/capability lost in translation
- Group level focus
- Adopted an MBSE approach to System Development
- Is a common framework possible?
- MBSE Capability Models taking off within CDG → Could these be linked to M&S?

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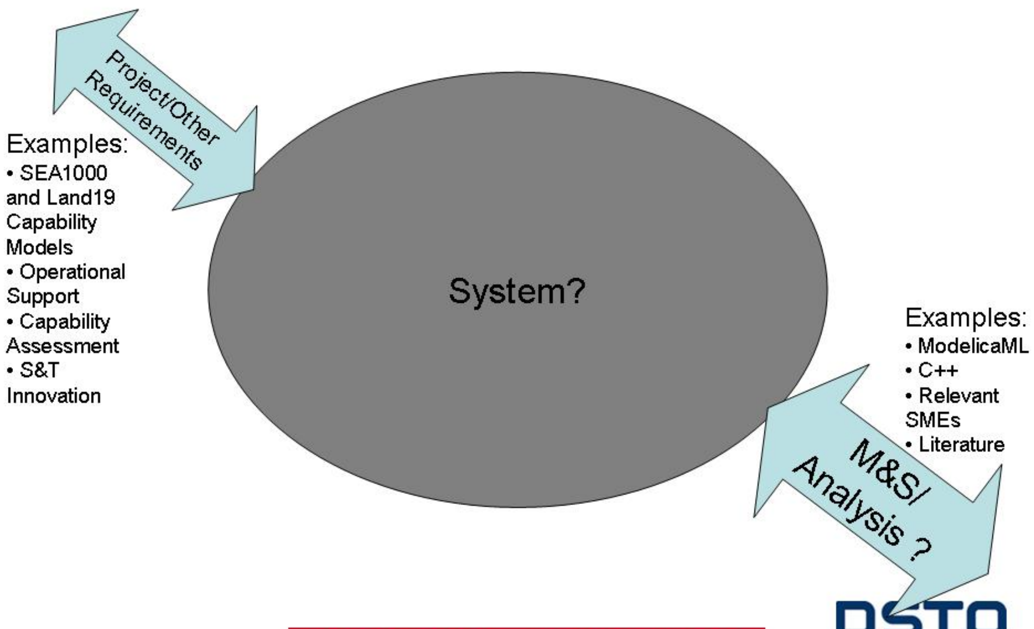
System-of-Interest



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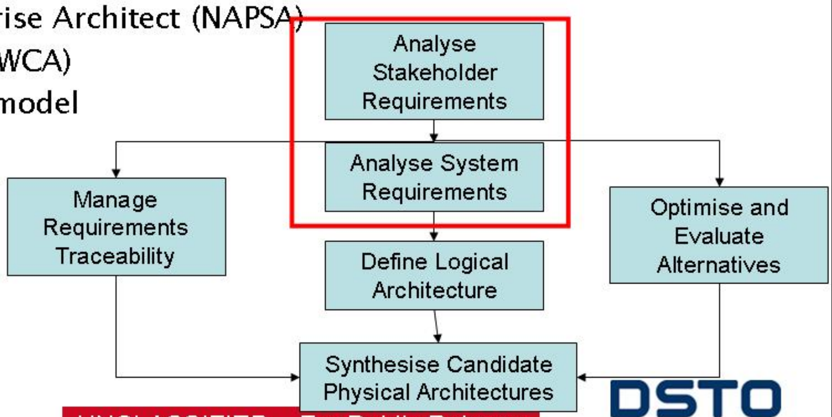
MBSE Approach

- Adopted OOSEM System Specification and Design Process [1] and Systems Engineering Handbook [2] (ISO/IEC15288 [3]) Exploratory Research processes
- Mirrors CDD Process [4] – i.e. operational scenarios to elaborate needs
- Tools
  - Enterprise Architect (NAPSA)
  - CORE (WCA)
- WSAF Metamodel



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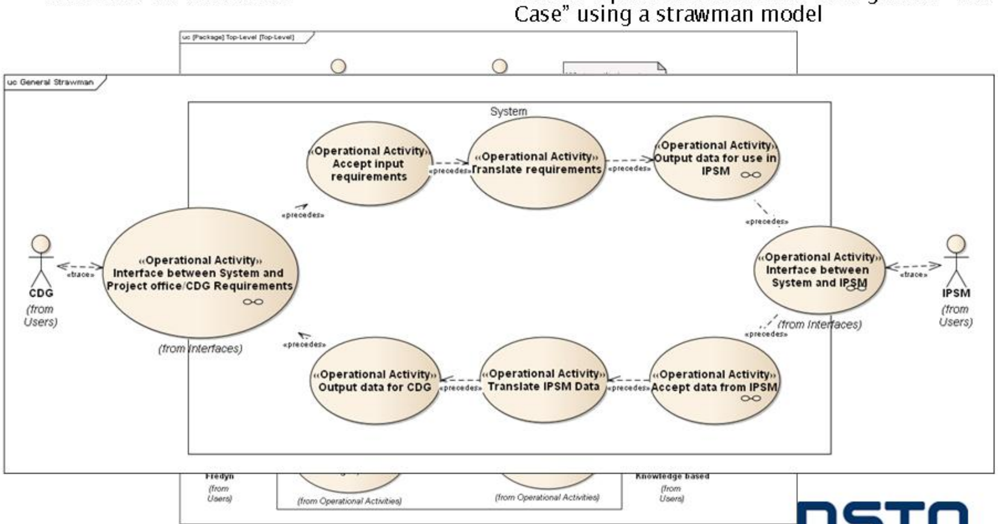
User Needs/Stakeholder Requirements Elicitation – NAPSA Workshop 1

- Outline the session and define MBSE terminology
- Elicit need statement
- Structured Brainstorming
- Minimise "SE" discussion
- MBSE performed on-the-fly
  - Elicit Top-Level "Use cases" (i.e. questions the group has been, or are likely to be asked)
  - Rate the importance of each operational activity
  - Elicited Operational Activities for a general "Use Case" using a strawman model



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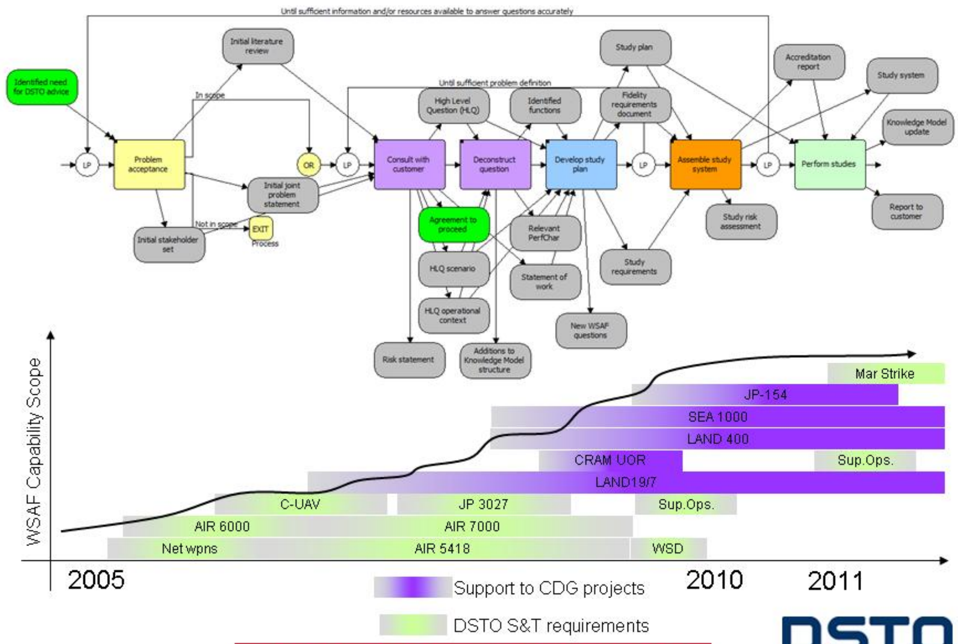
WSAF Evolution



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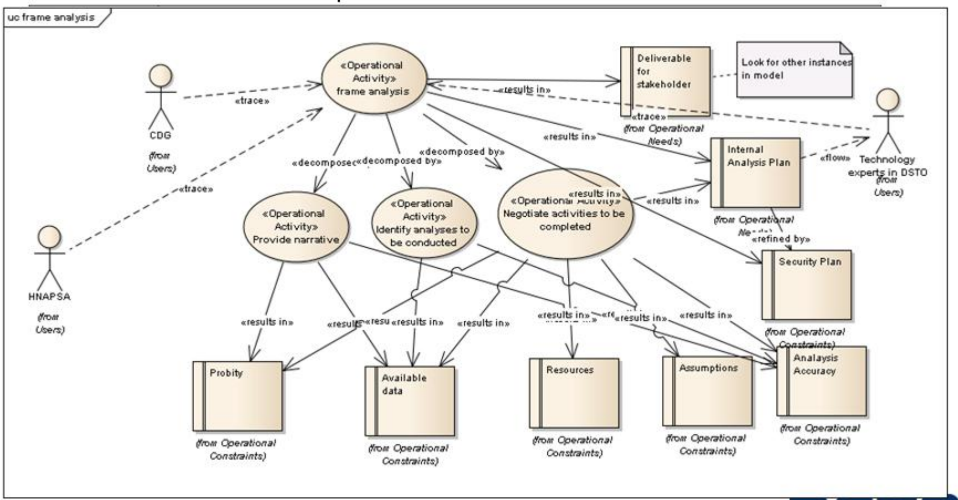
User Needs/Stakeholder Requirements Elicitation – NAPSA Workshop 2

- Similar participants to Workshop 1
- Review of the need statement
- Structured Brainstorming
- Used model from 1st workshop
- MBSE performed on-the-fly
- Elaborated Top-Level Use Case FFBD (operational activities)
- Elicited operational needs and constraints



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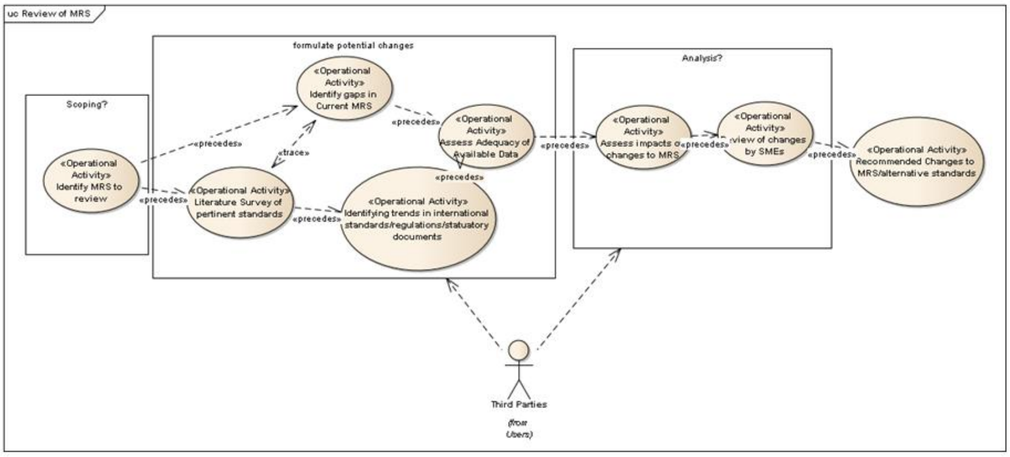
User Needs/Stakeholder Requirements Elicitation – NAPSA Workshop 3

- Elaborated another top-level Use Case
- Blank Canvas
- Restricted participants to 5-8 operational activities



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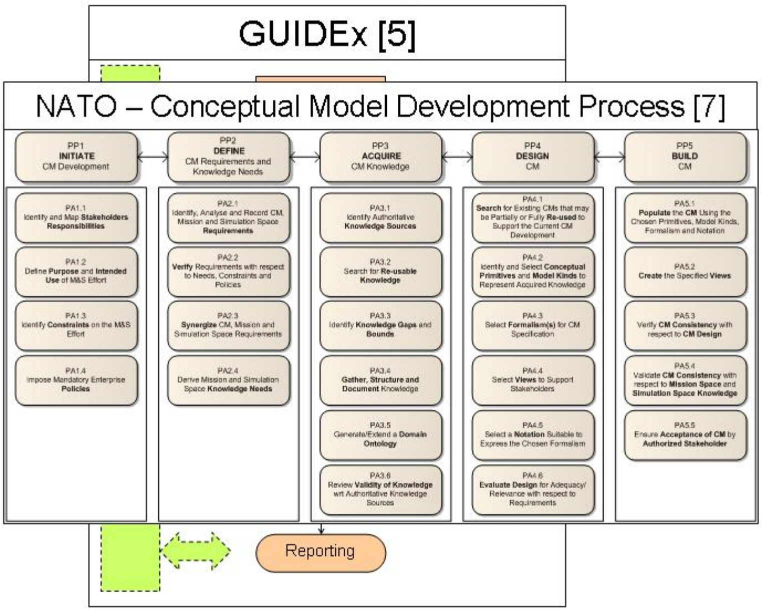
Frameworks for Conducting Analysis



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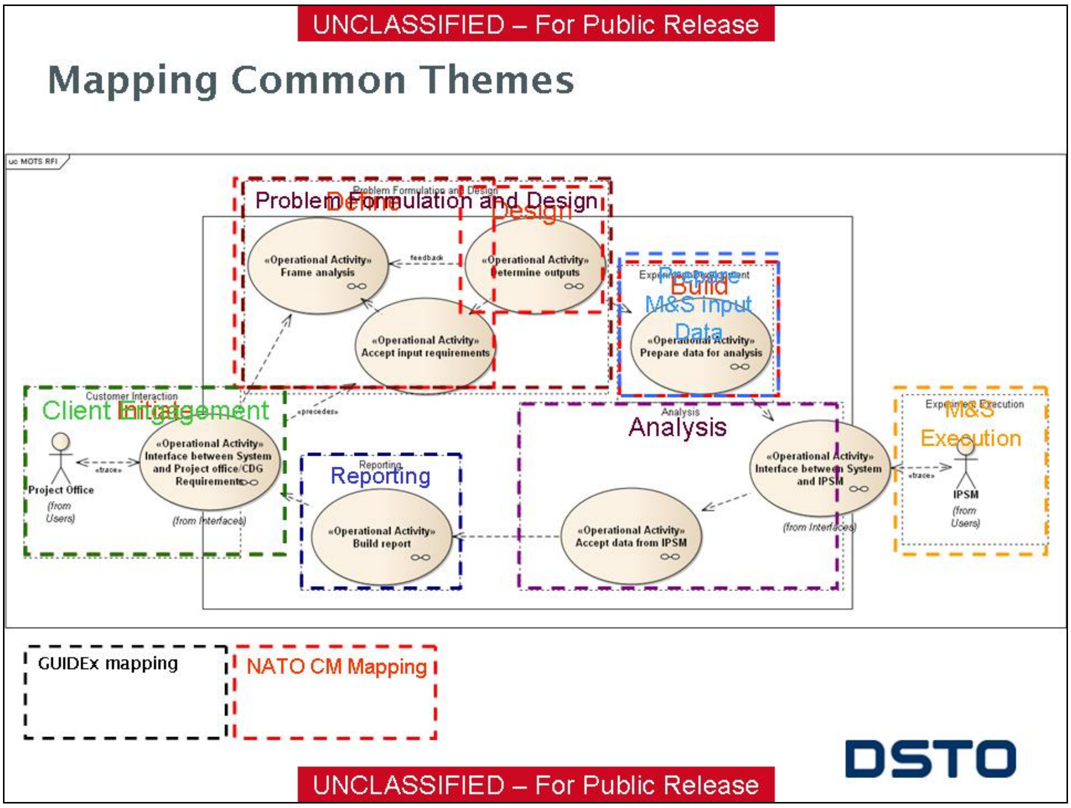
UNCLASSIFIED – For Public Release
Mapping Common Themes
uc MOTS RFI
Problem Formulation and Design
Define
Design
«Operational Activity» Frame analysis
feedback
«Operational Activity» Determine outputs
«Operational Activity» Accept input requirements
Build
M&S input
Data
«Operational Activity» Prepare data for analysis
Customer Interaction
Client Engagement
Project Office
(from Users)
«trace»
«Operational Activity» Interface between System and Project office/CDG Requirements
(from Interfaces)
«precedes»
Reporting
«Operational Activity» Build report
Analysis
«Operational Activity» Accept data from IPSM
«Operational Activity» Interface between System and IPSM
(from Interfaces)
Experiment Execution
M&S
Execution
IPSM
(from Users)
GUIDEx mapping
NATO CM Mapping
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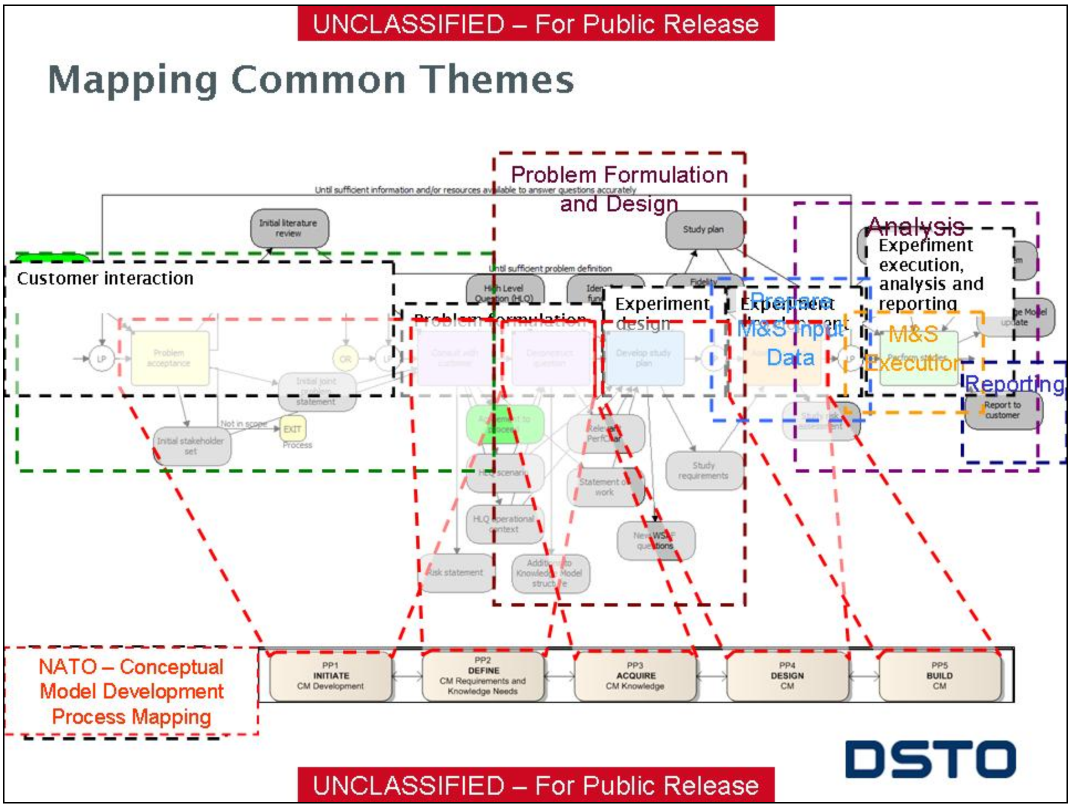
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Mapping Common Themes
Problem Formulation
and Design
Until sufficient information and/or resources available to answer questions accurately
Initial literature review
Study plan
Analysis
Experiment execution, analysis and reporting
Customer interaction
Until sufficient problem definition
Experiment design
Experiment
Prepare
M&S input
Data
M&S
Execution
Reporting
Report to customer
Study requirements
NATO – Conceptual Model Development Process Mapping
PP1 INITIATE CM Development
PP2 DEFINE CM Requirements and Knowledge Needs
PP3 ACQUIRE CM Knowledge
PP4 DESIGN CM
PP5 BUILD CM
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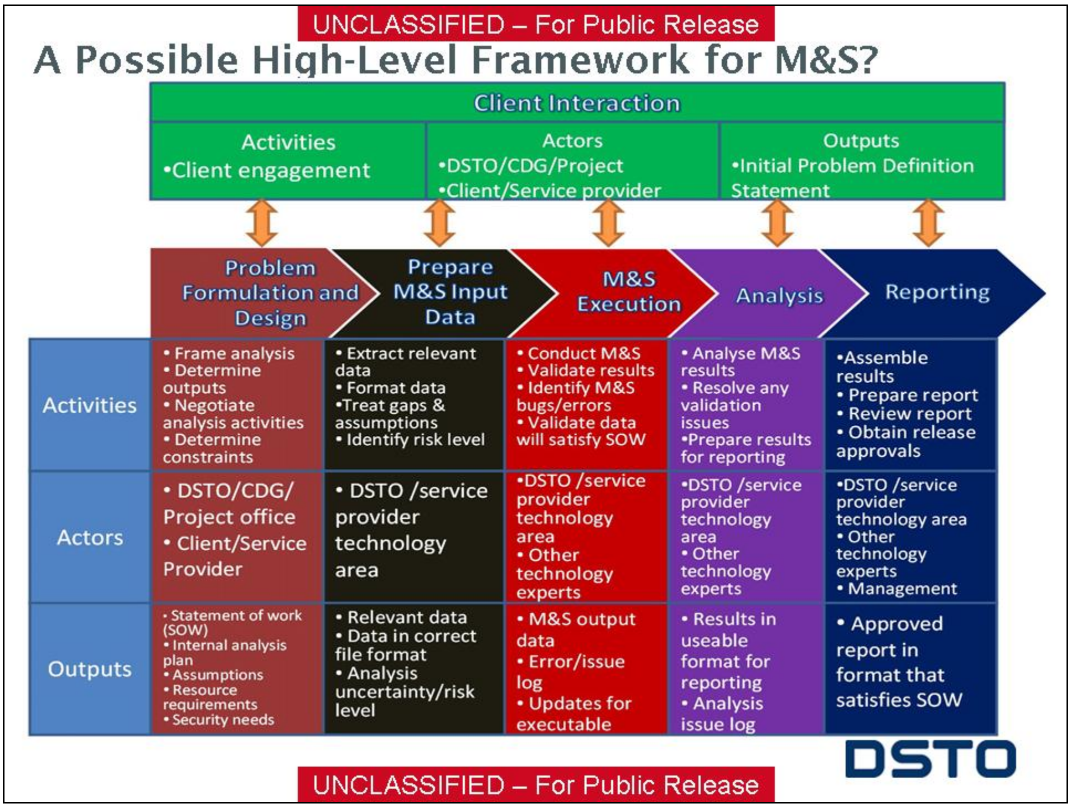
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A Possible High-Level Framework for M&S?
Client Interaction
Activities
•Client engagement
Actors
•DSTO/CDG/Project
•Client/Service provider
Outputs
•Initial Problem Definition Statement
Problem Formulation and Design
Prepare M&S Input Data
M&S Execution
Analysis
Reporting
Activities
• Frame analysis • Determine outputs • Negotiate analysis activities • Determine constraints
• Extract relevant data • Format data •Treat gaps & assumptions • Identify risk level
• Conduct M&S • Validate results • Identify M&S bugs/errors • Validate data will satisfy SOW
• Analyse M&S results • Resolve any validation issues •Prepare results for reporting
•Assemble results • Prepare report • Review report • Obtain release approvals
Actors
• DSTO/CDG/ Project office • Client/Service Provider
• DSTO /service provider technology area
•DSTO /service provider technology area • Other technology experts
•DSTO /service provider technology area • Other technology experts
•DSTO /service provider technology area • Other technology experts • Management
Outputs
• Statement of work (SOW) • Internal analysis plan • Assumptions • Resource requirements • Security needs
• Relevant data • Data in correct file format • Analysis uncertainty/risk level
• M&S output data • Error/issue log • Updates for executable
• Results in useable format for reporting • Analysis issue log
• Approved report in format that satisfies SOW
DSTO
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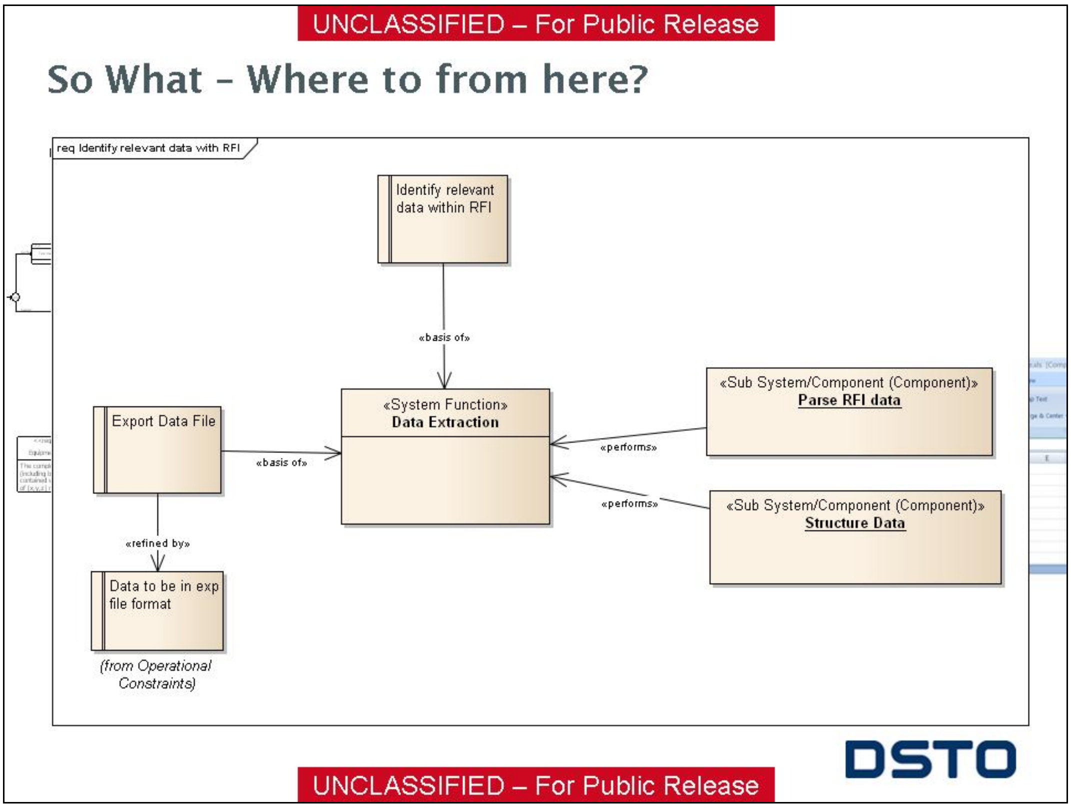
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So What – Where to from here?
req Identify relevant data with RFI
Identify relevant data within RFI
«basis of»
«System Function» Data Extraction
Export Data File
«basis of»
«refined by»
Data to be in exp file format
(from Operational Constraints)
«Sub System/Component (Component)» Parse RFI data
«performs»
«performs»
«Sub System/Component (Component)» Structure Data
DSTO
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Lessons Learned

- Avoid any emphasis on "we are doing SE"
- Be aware of personalities – e.g.
  - Functional thinking not inherent – give them time to explore
  - People down in the weeds
- Importance of a broad range of stakeholders
- By the third NAPSA workshop, participants had process buy in
  - Positive feedback
  - Able to work with a blank canvas
- Having two facilitators at NAPSA workshops was beneficial
- You can perform modelling on-the-fly – and it aids elicitation!

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Conclusions

- Large amount of Human/negotiating activities within interface
- Possible High-level framework only applicable to Defence/DSTO at present
- MBSE on-the-fly is useful in concept engineering – particularly needs elicitation
- Potential exists to link some of the identified operational activities/functions to components in an interface between MBSE capability models and M&S
  - This is likely to be important with the growing use of MBSE capability models in Defence

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References

1. Friedenthal, S., Moore, A. and Steiner, R. (2009) *A Practical Guide to SysML: The Systems Modeling Language*. Burlington, MA, Morgan Kaufmann OMG Press
2. Haskins, C. (ed.) (2010) *Systems Engineering Handbook: A Guide for System life Cycle Processes and Activities*. 3.2 ed., San Diego, INCOSE
3. ISO/IEC (2008) *Systems and Software Engineering - System Lifecycle Processes*. In *15288:2008*. USA. ISO/IEC-IEEE.
4. Defence (2009) *Defence Capability Definition Documents Guide*. Department of Defence, Canberra. DMO.
5. TTCP (2006) *Guide for Understanding and Implementing Defense Experimentation (GUIDEx)*. The Technical Cooperation Program
6. TTCP (2011) *Modelling Framework fro Network Enabled Weapons: A Function and Signal Specification (FaSS)*. The Technical Cooperation Program
7. NATO (2012) *Conceptual Modelling (CM) for Military Modeling and Simulation (M&S)*. NATO Science and Technology Organisation

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DSTO

7. Enhancing the Clarity of Low Level Decisions on the Goals of Large Complex Projects

Robert Dow, Lyn Dow, LCDR Kim Baddams and David Kershaw
Maritime Operations Division, DSTO

Abstract

The aim of the work is to examine the possibility of developing a tool to track, monitor and predict large complex system development by enhancing the clarity of how decisions at lower levels impact on the goals of the project. The approach uses Maritime Operations Division's (MOD) established ability in combat system performance modelling using MBSE and attempts to connect that level to Operational Capabilities and hence Strategy.

The paper leverages off MBSE tool capabilities, developments such as the Whole of System Architecture Framework (WSAF) and research approaches such as the Aligned Process Model (APM). The large complex project examined in this experiment is the Future Submarine project due to the authors' experience with the project, however any other large complex project would have been equally viable for the experiment.

Presenter Biography

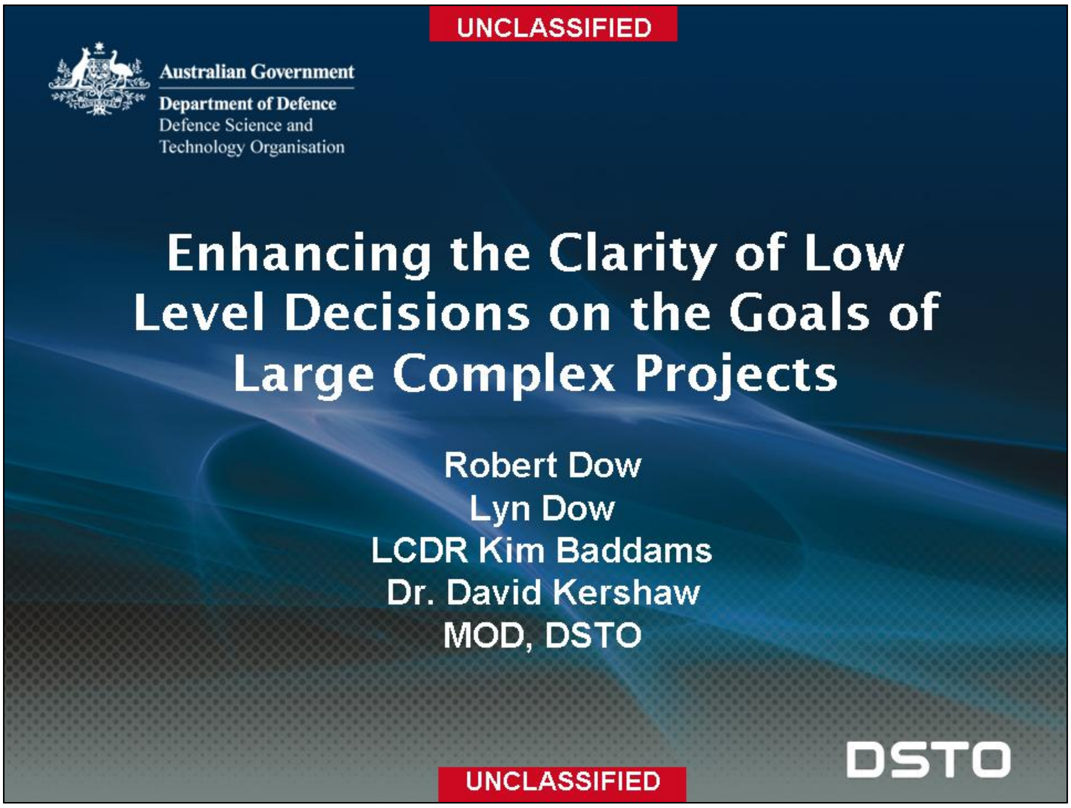
Robert Dow graduated from James Cook University of North Queensland with Bachelor of Engineering and Master of Engineering Science Degrees in 1974. His professional engineering and scientific research career includes designing Army man-pack radios at Army Design Establishment, Maribyrnong, Victoria (1974-77); scientific instrumentation and CNC machines (1977-84) in the Engineering Division of Materials Research Laboratory (MRL); then research into sea mine target detection logic in Explosives Division of MRL (1984-1989). From the early 1990's within Maritime Operations Division he looked after a team supporting the Mine Warfare Systems Centre Project, RAN Mine Warfare Exercises and research into artificial neural networks for ordnance. He moved to MOD, DSTO-E, Adelaide in 1998 where he has worked on MBSE in support of combat systems for surface combatants and submarines. Robert Dow currently works on MBSE for Combat Systems within the Submarine Combat System Group of the Submarine Systems Branch, Maritime Operations Division, DSTO-E.

Lyn Dow has Higher Technician's Certificates from Footscray Institute of Technology in mechanical and electrical engineering. She worked in Dimensional Metrology in Materials Research Laboratory (MRL) (1970-1972), Electrical Metrology (1972-1974, 1976-1978), Camouflage (1974-1976), and Electronics (1978-1983). Returning to work in 1989, Lyn provided LAN network, computer and executive support in Maritime Operations Division. She moved to MOD, DSTO-E, Adelaide in 1998 where she has worked on MBSE in support of combat systems for surface combatants. Lyn Dow currently works on MBSE for Maritime Warfare Operations Group of the Surface Ship Operations Branch, Maritime Operations Division, DSTO-E.

Kim Baddams served in the Royal Australian Navy from 1973 to 1998, qualifying as a fighter pilot, Air Warfare Instructor, and Principal Warfare Officer specialising in anti-submarine warfare. He held staff positions in the Naval Warfare Branch of Navy Office, where he was the inaugural Director Above and Underwater Warfare, and in the Maritime Development branch of Defence Capability Development. Since leaving full time service he has worked as a Naval Reserve in support of Navy tasks at the Defence Science and Technology Organisation, including considerable involvement with Model Based System Engineering. His qualifications include a Diploma of Maritime Studies and a Graduate Diploma of Applied Science.

David Kershaw started in Defence as a Cadet Engineer with Navy Material in 1987 and transferred to DSTO in 1989. He holds a B.Sc(Hons) in Physics, a B.E in Electrical and Computer Systems Engineering and a PhD in Tracking Systems. Positions held within DSTO have included Head of Torpedoes & Torpedo Defence Group (1999 through to 2002), Navy Scientific Adviser (2003-04), Air Warfare Destroyer S&T Adviser (2005-06), Acting Research Leader in Surface Ship Operations (Sept 2006-March 07), Head Torpedo Systems Group (2007-2010), and Head Submarine Combat Systems Group (2010-2012). David was appointed as the Research Leader Submarine Systems and SEA 1000 (Future Submarine) S&T Adviser in early 2012.

Presentation



The Challenge

To support the Decision Maker, we want to look at the possibility of **developing a tool to monitor large complex system development** by enhancing the **clarity of how decisions at lower levels** impact on the **goals of the project**.

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The V-model of the Systems Engineering Process

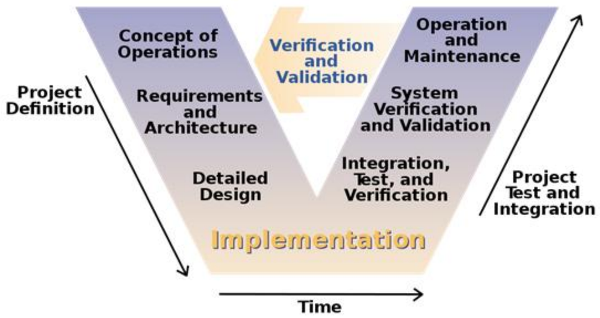

Image extracted from *Clarus Concept of Operations*. Publication No. FHWA-JPO-05-072, Federal Highway Administration (FHWA), 2005

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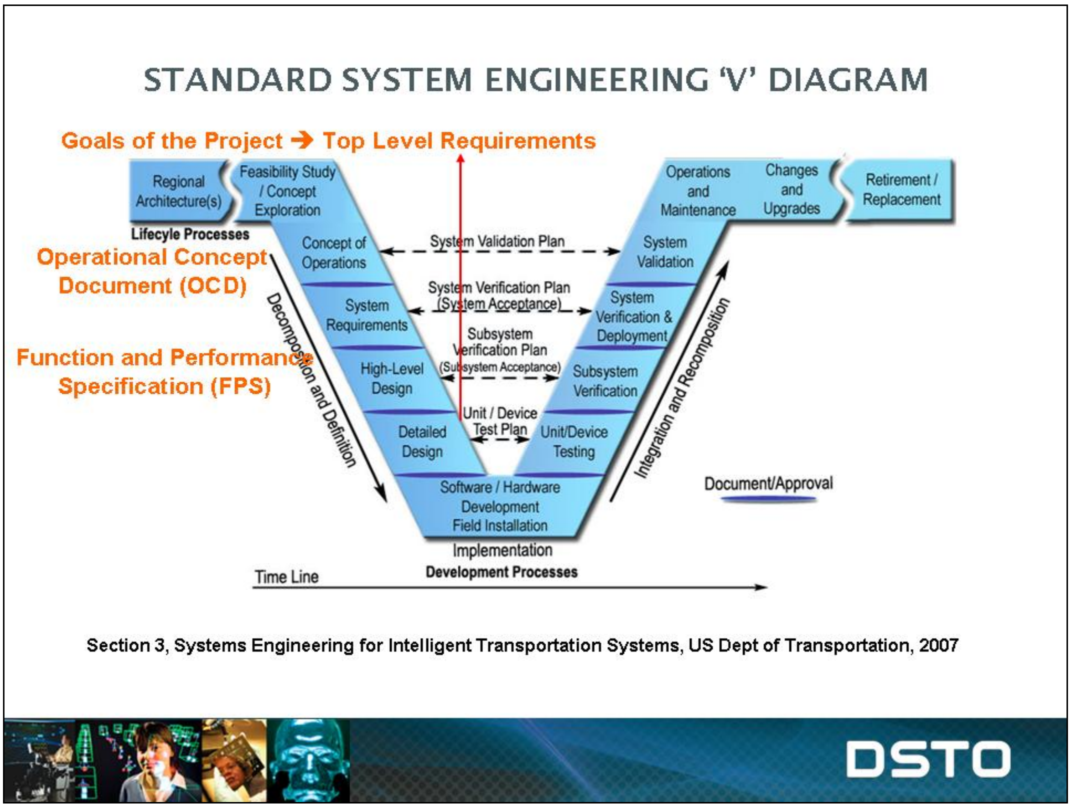
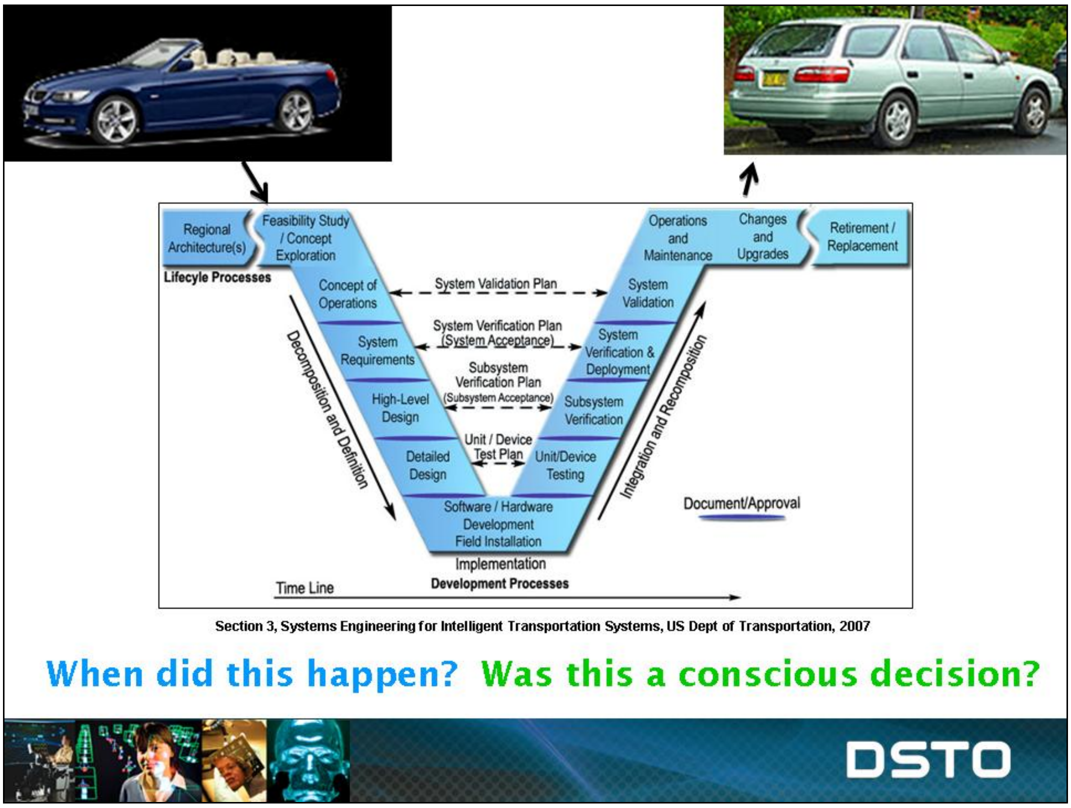

STANDARD SYSTEM ENGINEERING 'V' DIAGRAM
Goals of the Project → Top Level Requirements
Operational Concept Document (OCD)
Function and Performance Specification (FPS)
Regional Architecture(s)
Feasibility Study / Concept Exploration
Lifecycle Processes
Concept of Operations
System Requirements
High-Level Design
Detailed Design
Software / Hardware Development Field Installation
Implementation
Development Processes
Unit/Device Testing
Subsystem Verification
System Verification & Deployment
System Validation
Operations and Maintenance
Changes and Upgrades
Retirement / Replacement
System Validation Plan
System Verification Plan (System Acceptance)
Subsystem Verification Plan (Subsystem Acceptance)
Unit / Device Test Plan
Decomposition and Definition
Integration and Recomposition
Document/Approval
Time Line
Section 3, Systems Engineering for Intelligent Transportation Systems, US Dept of Transportation, 2007
DSTO


Regional Architecture(s)
Feasibility Study / Concept Exploration
Lifecycle Processes
Concept of Operations
System Requirements
High-Level Design
Detailed Design
Software / Hardware Development Field Installation
Implementation
Development Processes
Unit/Device Testing
Subsystem Verification
System Verification & Deployment
System Validation
Operations and Maintenance
Changes and Upgrades
Retirement / Replacement
System Validation Plan
System Verification Plan (System Acceptance)
Subsystem Verification Plan (Subsystem Acceptance)
Unit / Device Test Plan
Decomposition and Definition
Integration and Recomposition
Document/Approval
Time Line
Section 3, Systems Engineering for Intelligent Transportation Systems, US Dept of Transportation, 2007
When did this happen? Was this a conscious decision?
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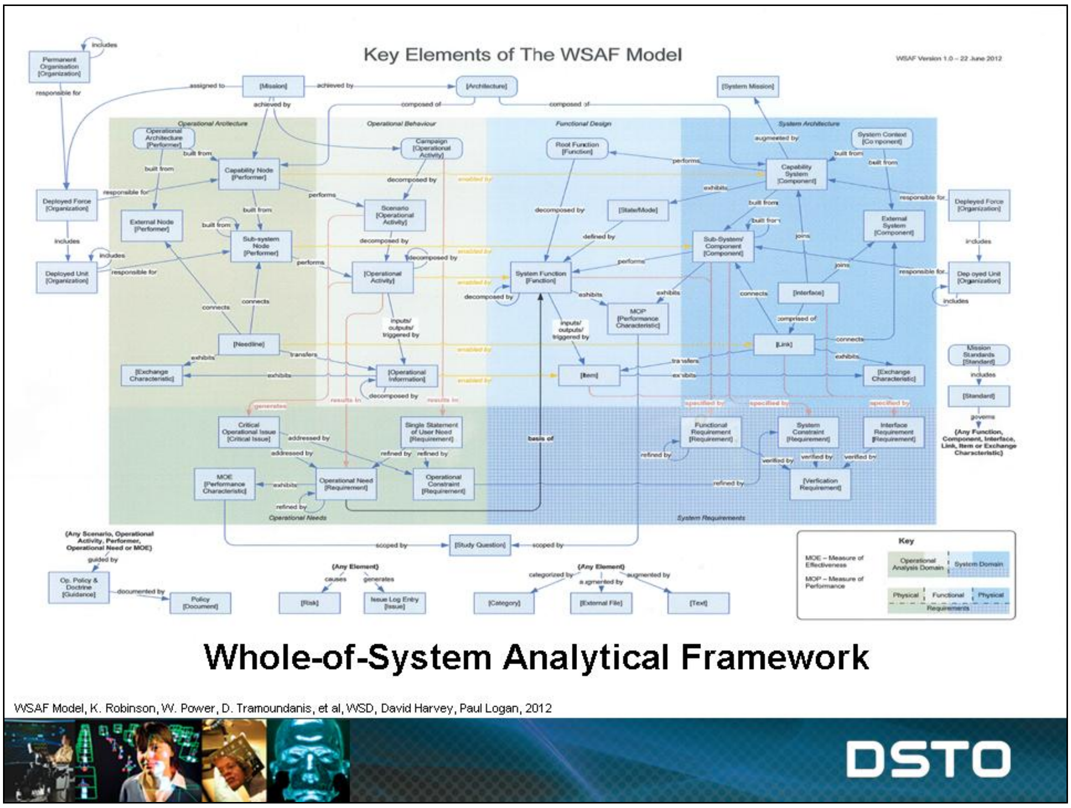
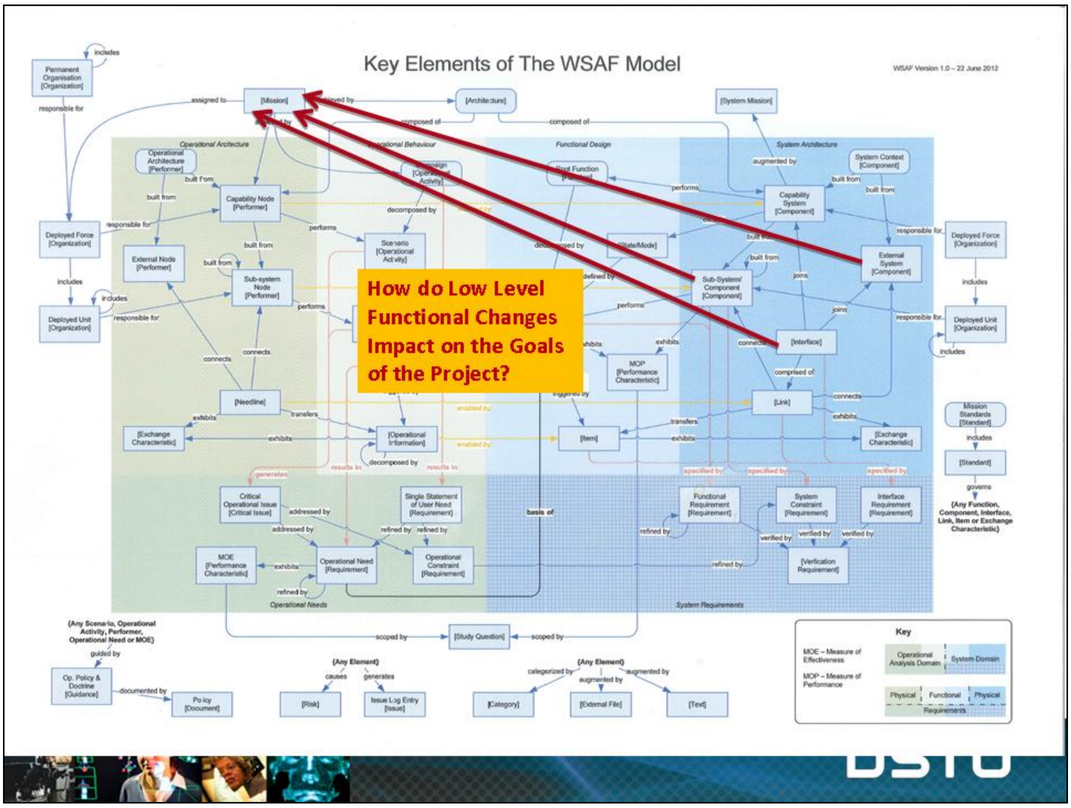

Key Elements of The WSAF Model
WSAF Version 1.0 – 22 June 2012
Whole-of-System Analytical Framework
WSAF Model, K. Robinson, W. Power, D. Tramoundanis, et al, WSD, David Harvey, Paul Logan, 2012
DSTO


Key Elements of The WSAF Model
WSAF Version 1.0 – 22 June 2012
How do Low Level Functional Changes Impact on the Goals of the Project?

Capability Development Life Cycle - Responsibilities

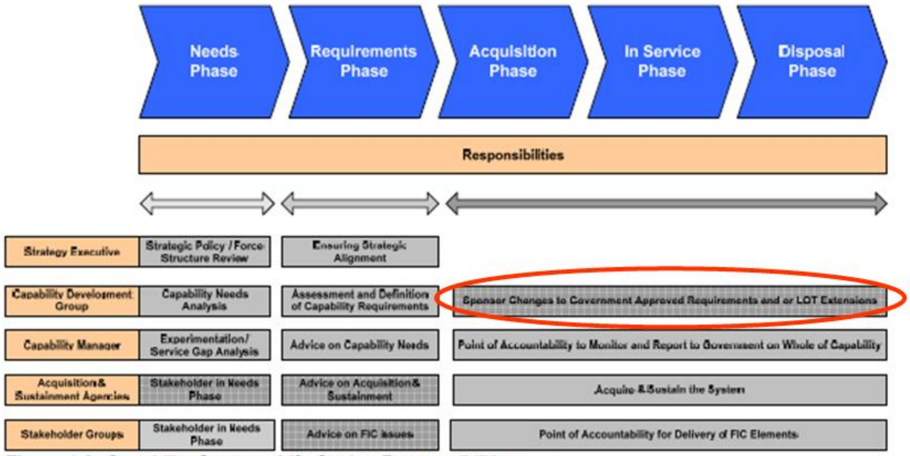


Figure 1-2: Capability Systems Life Cycle - Responsibilities

Defence Capability Development Handbook, Commonwealth of Australia, 2011

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The Challenge

Three reasons why this could get difficult

1. **Developing a tool**

2. Applied to **large complex system development**

3. Attempts to **enhance the clarity of how decisions at lower levels impact on the goals of the project.**

Risk Increasing

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Rationale for the Proposed Tool

Requirement: Quantify how low level decisions impact on the goals of the Project.

When: During acquisition phase of Capability Development Lifecycle.

Why Not Done Now: complexity, cost and delay.

DSTO advice needs to be timely, accurate and independent

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Tool Requirements

1. Fast and automated, 1 week turnaround for advice,
2. Run with a minimum of manual effort,
3. Works across the entire MBSE Project database
4. Deliver results in formats readily understood by decision makers
5. Staffing limited for tool development and application

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Approach to Enhancing the Clarity of Low Level Decisions on the Goals of Large Complex Projects

1. Project Goals measured by submarine's ability to meet Top Level Requirements.

2. Achievement of Top Level Requirements tested by submarine behaviour within agreed defined scenarios and vignettes.

3. Submarine behaviour captured by executable functional chains containing probability distributions and analytical expressions.

4. Therefore measuring whether Project Goals are being met can be tested by executing submarine functional chains within scenarios and vignettes defined by the Top Level Requirements.

Approach Informed by Work in Other Types of Warfare

1. Mine Warfare Command Tactical Decision Aides
   Calculated effect of low level changes on MCM Task Group Operations. Used Monte Carlo simulations, analytical expressions, and probability theory.
   Must be calculated every task cycle.

2. Maritime Air Defence Combat System Performance Prediction using MBSE.
   Calculation time twelve hours once models built.

White Paper Strategic Roles of FSM

DEFENCE WHITE PAPER 2009:
Chapter 9 p70

The Future Submarine will be capable of a range of tasks such as;

1. Anti-ship warfare;
2. Anti-submarine warfare;
3. Strategic strike;
4. Mine detection and mine-laying operations;
5. Intelligence collection;
6. Supporting special forces (including infiltration and exfiltration missions);
7. Getting battlespace data in support of operations.

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Impact of High Level Function Failure on Project Goals

Tasks	ASuW	ASW	SS	MW	Intel	BD
Sonar Passive	X	X	X	X	X	X
Sonar Active		X				
Sonar HF Active				X		
ESM	X		X		X	X
Periscope	X		X		X	X
Bathometer				X		
Radio					X	
Mk 48 ADCAP	X	X				
Harpoon	X					
Land Attack			X			

Sub. Tasks - Defence White Paper 2009

ASuW	**Anti-Ship Warfare**
ASW	**Anti-Submarine Warfare**
SS	**Strategic Strike**
MW	**Mine Warfare**
Intel	**Intelligence Collection**
BD	**Battlespace Data**

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Tool Implementation – a possible approach

1. One complete high level function failure is not likely

2. Reality is marginal performance changes in some functions

3. Approach for tool construction: functional chains executing scenarios and vignettes with MBSE

4. Functions incorporate external information: analytic expressions, tables, graphs, probability distributions etc.

5. MBSE Model execution tightly connected to Operational Requirements, Architecture and System Engineering database.
    - Removes translation errors between models
    - Enables cross referencing within MBSE database

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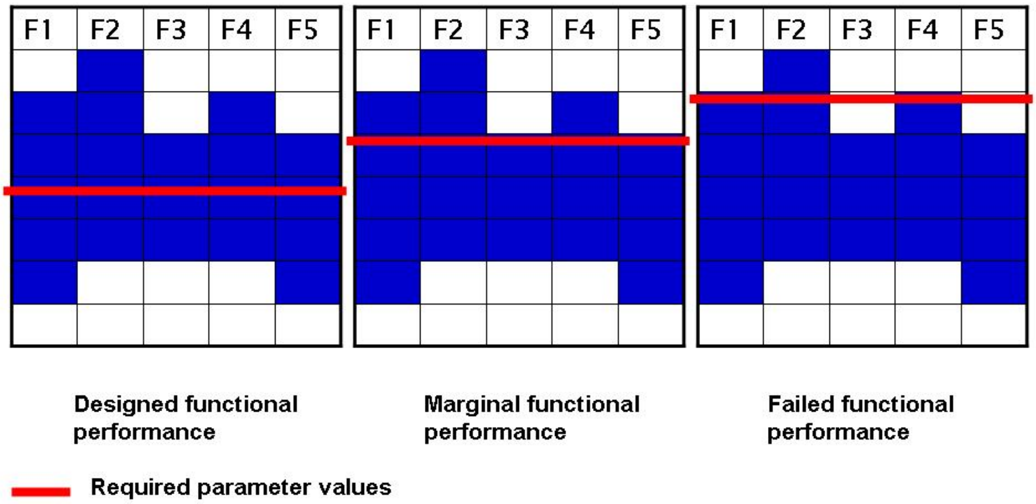
Illustration of Designed, Marginal and Failed Functional Behaviour



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Mine Warfare Modelling - Levels of Abstraction

Level	Type of model	Characteristics of model
Mine-target sweep interaction, MH Sonar, single asset against single mine type	Detailed physics (magnetic acoustic sweep, sonar hunt) using MC simulation	Large, detailed taking weeks to provide results as cross channel profile MoP's
Single Asset, Single Pass, multiple mine type, sweep or hunt	Calculation of single pass for a single asset against multiple mine threats MoP	Equation combining single pass cross channel MoP to multiple mine clearance cross channel MoP
Single asset, multiple pass, sweep or hunt	Calculation of multiple pass, single asset against multiple threats MoP	Complex equation transforming single pass MoP to a single asset, multiple pass MoP (Clearance plot)
Multiple Asset, multiple pass combined hunting and sweeping	Calculation of combined clearance for hunting and sweeping assets	Complex equation working from a plot combining achieved Clearance from single assets MoP to multiple assets Clearance Level (Combined Clearance MoP)
Correlate mines removed plot with Clearance plot to provide MoE for threat to transitor	Calculation of mines remaining and threat to transitor	Simple (but very clever) calculation of MoE

Calculation Done within 12 hour Tasking Cycle

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Submarine Warfare Modelling – Levels of Abstraction

Level	Type of Model	Characteristics of Model
Basic Functions: sensors, weapons, information management, platform models	Detailed physics models, Integrated Platform System Model	Large, detailed, major effort to maintain, slow to generate results (months) possibly as probability or sub-function
CS functions: Detection, TMA, Targeting, SINS POE, …	Single sub-function performance model in CORE including effects such as probability distributions and computing resources	EFFBD execution with internal calculation. A probability distribution or a sub-function model could be used in the next level.
Target engagement	CS model execution (prior example ANZAC Extant)	EFFBD execution with internal calculation. Output: probability distribution or a sub-function model could be used in the next level.
Multiple Target engagement	CS model of multiple Target engagement (prior example ANZAC ASMD)	EFFBD execution with internal calculation. Output: probability distribution or a sub-function model could be used in the next level.
Task (Described in DoDAF CORE. Application should model defined scenarios with sufficient accuracy)	Defined scenario DoDAF CORE Operational model	EFFBD execution with internal calculation: Output result in format suitable for Decision Makers i.e. Probability/Traffic Light colour

Calculation Done within One week

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Layout of the Modelling Layers Contained within 'Clarity' Tool & How it Can Support Timely Decisions

1. Detailed models from:
   The Integrated Platform System Model (MPD, DSTO) for whole of submarine margins
   Physics and engineering for sensors and weapons
   With Prior modelling calculation time - weeks

2. Executable models in MBSE (CORE).
   Use 'distilled' information from above within MBSE Functions
   Submarine functional chain execution in scenarios & vignettes
   Informed by Operations Research
   Parametric analysis (minimal) - changes in few low level functions
   Computation time - days

3. Final layout of results in formats for decision makers
   May require information display tools outside MBSE (CORE)

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Challenges for Tool Development

1. Inputting the FSM Project into MBSE
   1.1 Helpful:
   Capability Development using WSAF (MBSE CORE)
   Should have two – five years

   1.2 Difficult:
   Low level changes to functions need detailed implementation – may be difficult within Project response times

2. Moving between operations and engineering understanding of parameter values during Project?

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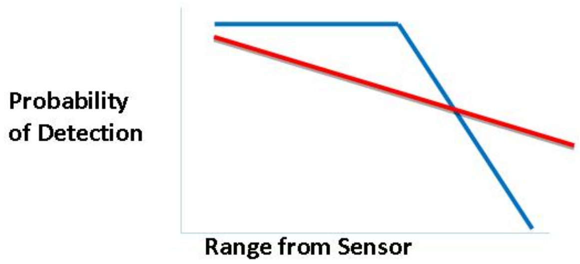
Engineering vs Operations Understanding of Parameter Values

1. Operational performance measured from operational/exercise analysis vs.

2. Engineering Performance calculated from physics and engineering signal processing



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Is it worth doing?

How else might it be done?

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8. Employing Concept Definition Techniques to Deliver Value on the RAN Air Warfare Destroyer Program

Steven J. Saunders
Raytheon Australia

Abstract

Modern, complex development systems pose risks in defining the right system solution, building/integrating/delivering the capability and sustaining the capability through the complete lifecycle of that system. Major defence acquisition programs, like the SEA 4000 Royal Australian Navy (RAN) Air Warfare Destroyer (AWD) Program are no different. This presentation describes concept engineering processes employed on the AWD combat system during the capability definition stage of the Program.

Concept definition is a critical activity of any major system development, requiring a balanced approach to multiple stakeholder considerations. The AWD Program has met this challenge by employing a collaborative team approach, early systems architecting and judicious use of Model Based Systems Engineering (MBSE). In this presentation, it is shown how Operational Activity models and supporting architectural views have been successfully used to communicate the system capability with the AWD capability sponsors. As the program has progressed, this MBSE environment has been progressively expanded to include additional SysML system composition and system behaviour model elements to support the system definition activities. A significant "by-product" of the system model has been the ability to identify, quantify and perform technical risk assessment on all system interfaces in order to provide a lead indicator of the cumulative integration risk to the program. Using this information, the architecture has been incrementally refined during concept definition in order to ensure the program integration risk has been minimized whilst ensuring other key stakeholder values have been satisfied.

Key lessons from this presentation demonstrate the applicability of MBSE techniques in complex/large programs and the reality that theoretical application of MBSE must be tailored and augmented with other visualisations and tools to communicate with the variety of stakeholders engaged in the concept definition phase of the program.

Presenter Biography

Steve Saunders, FIEAust CPEng, is an Engineering Fellow for Raytheon Australia. He received his Bachelor of Electrical Engineering from the University of Technology Sydney (UTS) with first class Honors in 1990. He has worked with Rockwell International, Boeing Australia and now Raytheon Australia on Australian Defence projects in various Systems Engineering Management, Requirements Development, Architecture, Design and Test roles. He is a Raytheon certified architect having completed the Raytheon Certified Architect Program in 2005.

Steve has been involved in the Royal Australian Navy's Air Warfare Destroyer Program since 2005 as the Combat System Chief Architect working in phase 2 of the Program to establish the Combat System architecture. He is now the AWD Combat System Chief Engineer and Combat System design authority.

Steve has written numerous articles on Systems Engineering and System architecting and has an interest in improving System Engineering and System Architecting maturity and the agility of Systems Engineering to support the rapidly evolving technology environment and complexity within the defence industry.

Presentation

Raytheon Australia

Agenda

- What is the Problem with Systems Engineering Today?
- How is Concept Engineering Used on the AWD Program
  - Background
  - MBSE Approach
  - Useful 'by-products'
- Lessons from the AWD Program
- Key Take-Aways
- Questions

The Term Concept Engineering is used to define the activities carried out in the "Concept Definition" phase of a Program

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What is the Problem with Systems Engineering (SE) Today?

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What is the Problem with SE Today?

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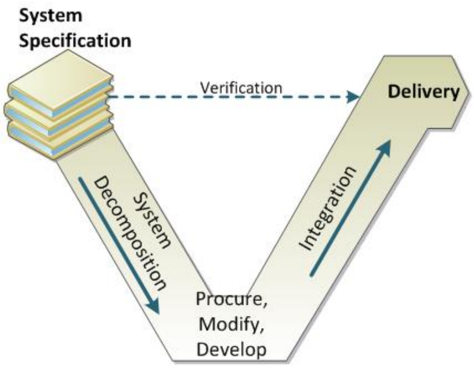
- The **'Easy'** Phases – Systems Requirement to Delivery



- Systems Engineering Processes are mature and well understood
- Transforms Requirements to verified System
- MBSE or Document Centric or Hybrid approaches applicable
- Reasonable tool support

But…

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What is the Problem with SE Today?

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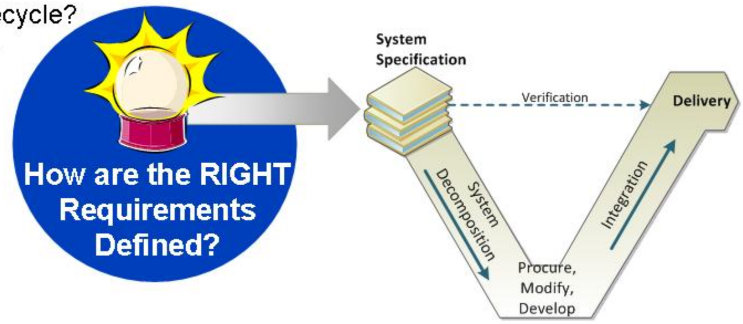
- Assertion → There is a Problem!
  - How are the **right** requirements defined?
    - Will the realisation of the requirements be affordable?
    - Can the requirements be verified?
    - Realisable in available technology?
    - Considers full lifecycle?
    - Meets the need?



Concept Definition (Concept Engineering)
Helps Ensure the Right Requirements are Specified

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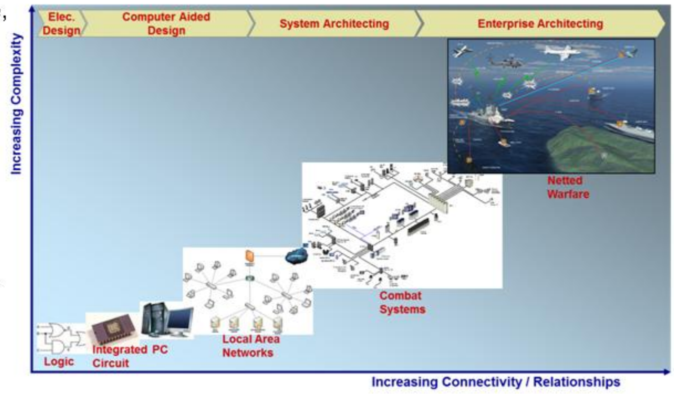
What is the Problem with SE Today?

- Why may Concept Definition Phase be Skipped or Superficially Addressed? -- It is HARD!
  - SOFT Engineering
    - Business Language,
    - Fuzzy Criteria,
    - Best fit rather than exact answers
  - It is COMPLEX…
    - Components
    - Systems
    - Enterprises
    - People / Processes
    - Sociological
    - Political
    - Environmental



Concept Definition is HARD(er) than System Definition
Often Overlooked – Has potential For High Impact on Program

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How is Concept Engineering used on AWD - Background

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- The Royal Australian Navy's (RAN) Air Warfare Destroyer (AWD) Program is employing a mix of strategies and contracting mechanisms to deliver a new major surface combatant to the RAN within an aggressive timeframe
- 8 Years to…
  - Select Equipment and Complete the Design
  - Build Shore Facilities & Integration Facilities
  - Build the Shipyard
  - Build the Lead Ship
  - Integrate and deliver the Capability

Courtesy AWD Alliance

- The AWD Program
  - has met major Program milestones,
  - has passed System CDR,
  - keel Layed – Future Destroyer HOBART
  - ship blocks for all 3 ships are in production,
  - has excellent customer relationships,
  - is scheduled to deliver the required capability to the RAN in 2016

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How is Concept Engineering used on AWD – A new Way of Doing Business

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- RAN Requires a new Capability "No Later Than" with Set Funding
- Schedule/Cost Constraints Require…
  - Collaboration between the Customer and the Mission System Integrator (MSI)
  - Stakeholders to Work Cooperatively for Improved Program Performance and Agility
  - Rapid Development of the Capability (MOTS/COTS vs New Development)
- Ensuring the System is Supportable for the Life of Type

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How is Concept Engineering used on AWD - Strategy: MBSE Approach

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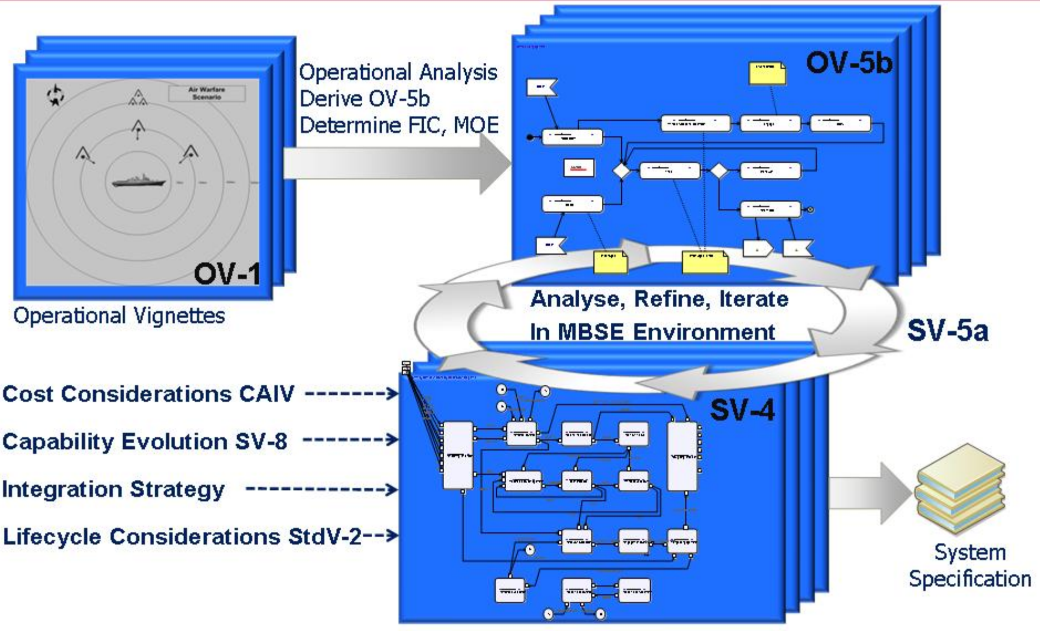

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How is Concept Engineering used on AWD – - Strategy: MBSE Approach

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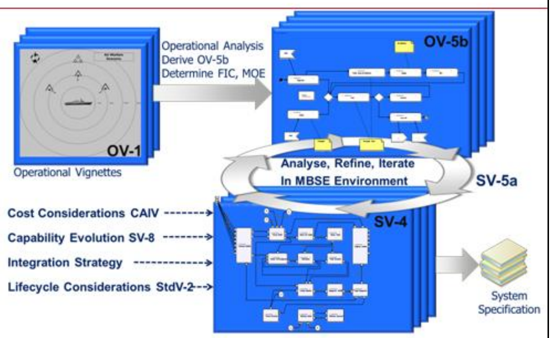
- Analyse using language of Capability Development Group
- Simplify Complexity using Architecting Practices
  - Model with Suitable Tools
- Analyse and Balance Considerations
  - Delivered Capability
  - Regulatory Compliance
  - Conformance to budget and schedule
  - Risk to delivery
  - System Evolution
  - Technology Evolution
- Iterate



Employ System Architecting to Analyse using Customer Language
Hide Complexity → Allow Balanced Decisions

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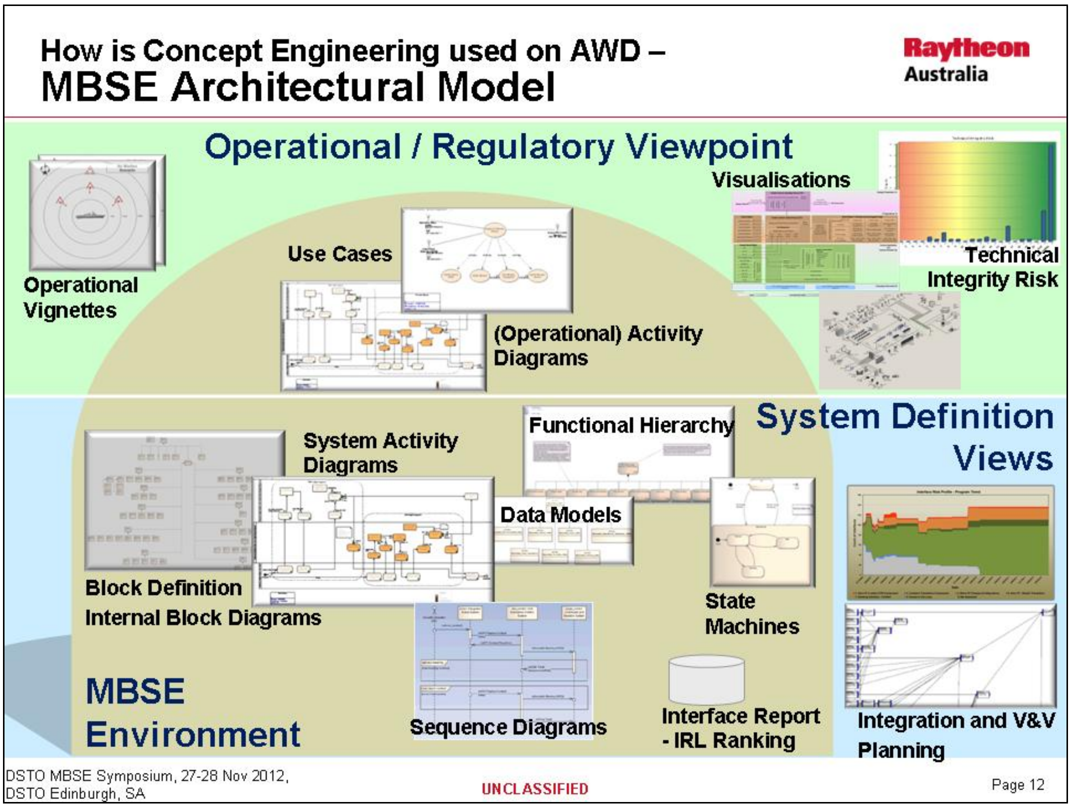
How is Concept Engineering used on AWD –
MBSE Architectural Model
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Operational / Regulatory Viewpoint
Visualisations
Technical
Integrity Risk
Operational
Vignettes
Use Cases
(Operational) Activity
Diagrams
System Activity
Diagrams
Functional Hierarchy
System Definition
Views
Data Models
Block Definition
Internal Block Diagrams
State
Machines
MBSE
Environment
Sequence Diagrams
Interface Report
- IRL Ranking
Integration and V&V
Planning
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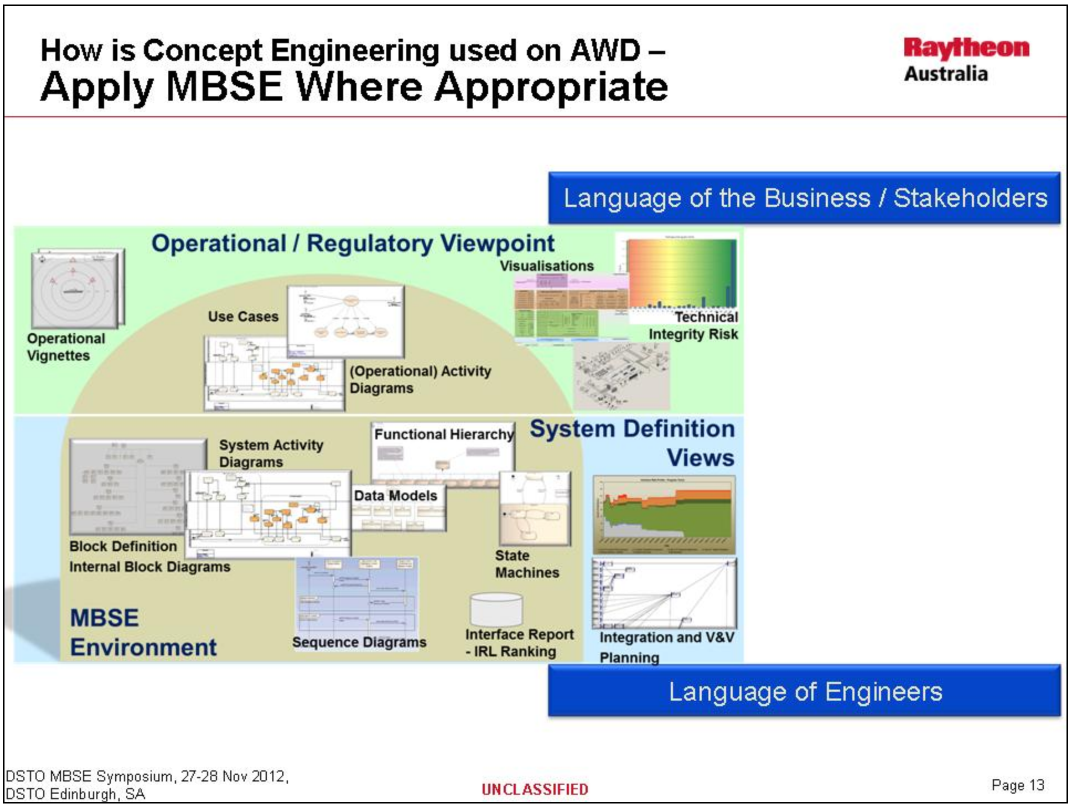
How is Concept Engineering used on AWD –
Apply MBSE Where Appropriate
Raytheon
Australia
Language of the Business / Stakeholders
Operational / Regulatory Viewpoint
Visualisations
Technical
Integrity Risk
Operational
Vignettes
Use Cases
(Operational) Activity
Diagrams
System Activity
Diagrams
Functional Hierarchy
System Definition
Views
Data Models
Block Definition
Internal Block Diagrams
State
Machines
MBSE
Environment
Sequence Diagrams
Interface Report
- IRL Ranking
Integration and V&V
Planning
Language of Engineers
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How is Concept Engineering used on AWD –
By-Product: Minimise Integration Risk

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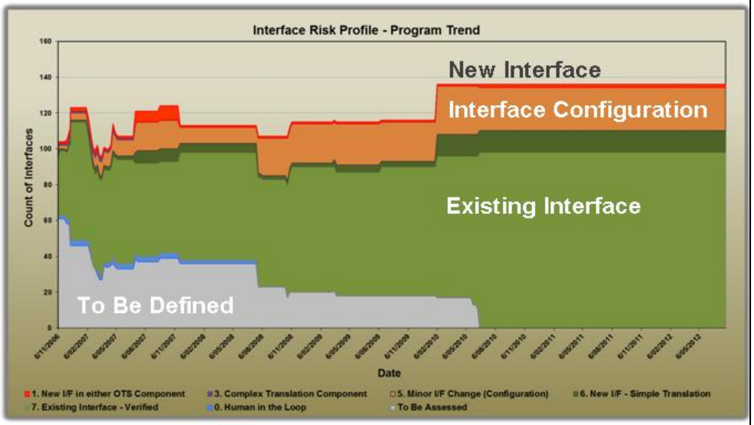
- Model contains all interfaces
  - Assign Interface risks (Interface Technology Level & Complexity)
  - Assess Risk Profile
  - Tune the Architecture
  - Minimise Integration Risk



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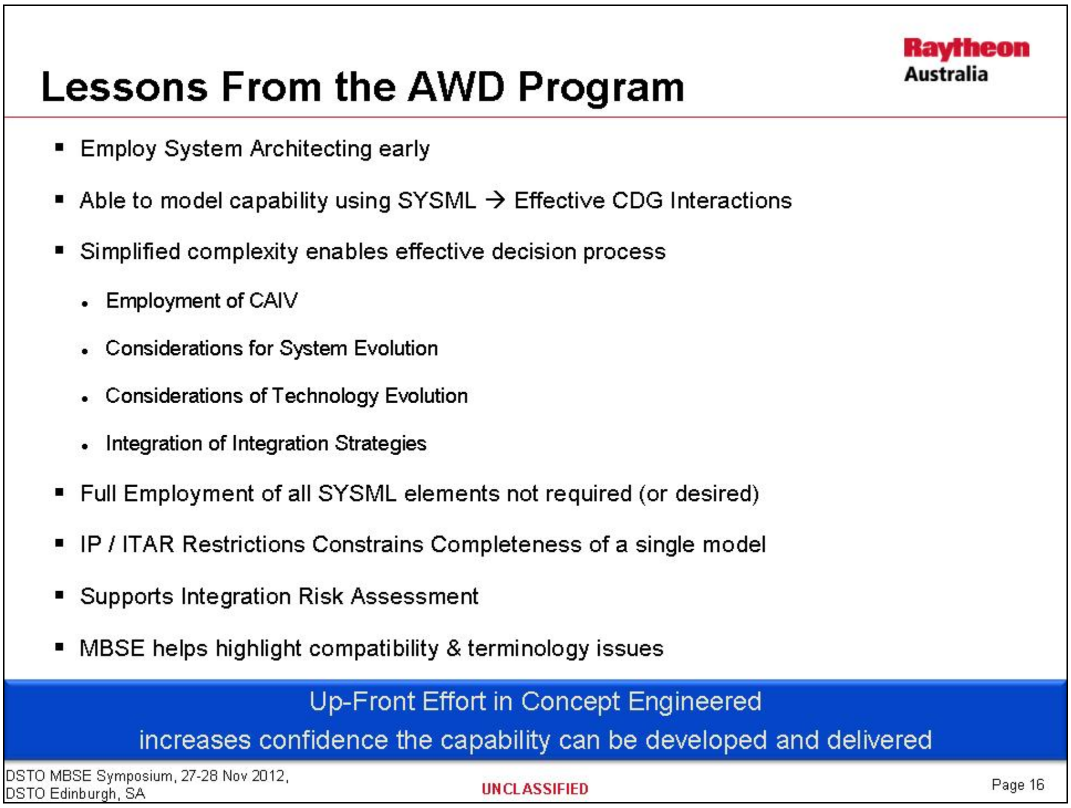
Lessons From the AWD Program
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Employ System Architecting early
Able to model capability using SYSML → Effective CDG Interactions
Simplified complexity enables effective decision process
Employment of CAIV
Considerations for System Evolution
Considerations of Technology Evolution
Integration of Integration Strategies
Full Employment of all SYSML elements not required (or desired)
IP / ITAR Restrictions Constrains Completeness of a single model
Supports Integration Risk Assessment
MBSE helps highlight compatibility & terminology issues
Up-Front Effort in Concept Engineered
increases confidence the capability can be developed and delivered
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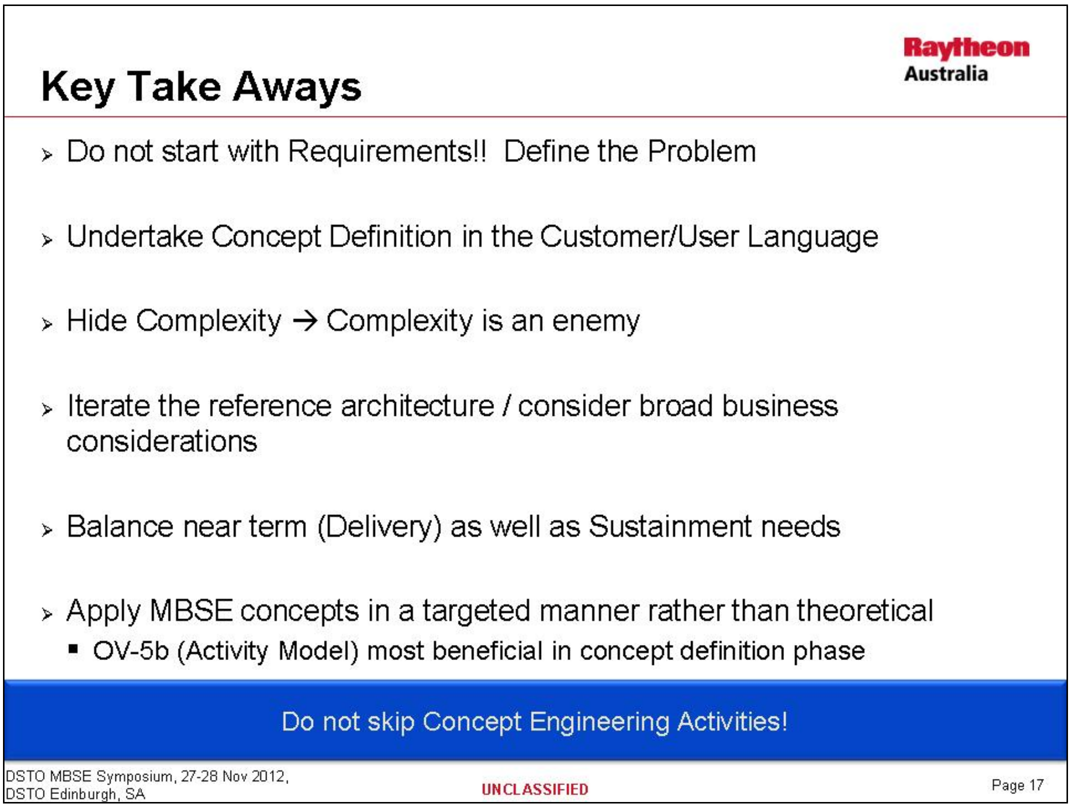
Key Take Aways
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Australia
Do not start with Requirements!! Define the Problem
Undertake Concept Definition in the Customer/User Language
Hide Complexity → Complexity is an enemy
Iterate the reference architecture / consider broad business considerations
Balance near term (Delivery) as well as Sustainment needs
Apply MBSE concepts in a targeted manner rather than theoretical
OV-5b (Activity Model) most beneficial in concept definition phase
Do not skip Concept Engineering Activities!
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Questions

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AWD MBSE Model "Factoids"

Data as at Oct 2012

49	Operational Vignettes
119	Use Cases
281	Segment Level Functions
787	Activities
948	Diagrams
42,222	Elements
16,069	Connections
106	Blocks in Logical Model
953	Blocks in Physical Model
432	Interface Messages

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Glossary

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- AWD — Air Warfare Destroyer
- CAIV — Cost as an Independent Variable
- CDG — Capability Development Group
- CDR — Critical Design Review
- COTS — Commercial Off the Shelf
- DoDAF — Department of Defense Architecture Framework, v2.0, 28 May 2009
- IP — Intellectual Property
- IRL — Interface Readiness Level
- ITAR — International Traffic in Arms Regulation
- MBSE — Model Based Systems Engineering
- MOTS — Military Off the Shelf
- MSI — Mission Systems Integrator
- OV-1 — Operational Concept Graphic (DoDAF v2.0)
- OV-5b — Operational Activity Model (DoDAF v2.0)
- RAN — Royal Australian Navy
- SE — Systems Engineering
- SV-4 — Systems Functionality Description (DoDAF v2.0)
- SV-5a — Operational Activity to Systems Traceability Matrix (DoDAF v2.0)
- SV-8 — Systems Evolution Description (DoDAF)
- SysML — Systems Modeling Language
- StdV-2 — Standards Forecast (DoDAF v2.0)

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9. WORKSHOP 1: What is a 'Capability System Model'?

Dr Michael Ryan
University of New South Wales

Abstract

In the current Defence acquisition system, the Capability System is described principally in the text-based Capability Definition Documents (CDD) set of documents, which are provided to potential prime contractors through a formal tendering process. Tenderers are required to digest the CDD in order to propose system-level solutions to the Materiel System. Tendered solutions are assessed by the customer for compliance with the CDD (as well as with other terms and conditions of the tender). This text-based process is often perceived as inefficient, with a high likelihood of errors. One way to overcome these shortcomings would be to use an MBSE approach to pass Capability System models across the contractual interface and integrate them to the Materiel System models included in the tendered solutions.

In an MBSE-supported system acquisition, however, the Materiel System is treated as a black box with its internal functions being subsequently defined by the tenderers in the solution space (presumably in a different way by each of the tenderers). To that end, the Capability System Models developed by the customer would treat the Materiel System as a single entity in order to show how it would be operated and supported in the operational environment. These Capability System Models would then be passed across the acquisition boundary so that tenderers can show how their tendered Materiel System model performs in the context of the Capability System Model.

In order to be in position to use a Capability System Model as part of the acquisition of a Materiel System, the customer must therefore undertake considerable modelling of the wider context of the Capability System as well as of the relevant Fundamental Inputs to Capability (FIC)[4] elements.

This workshop examines how a Capability Systems Model could be used to replace the existing text-based content of the CDD documents. In particular:

- The workshop will begin with an examination of the existing CDD in order to identify which elements of the existing documents can be replaced by the Capability System Model and which elements would need to remain text-based. Relevant documents include the Operational Concept Document (OCD) and the Function and Performance Specification (FPS).
- Attention will then turn to identifying the degree to which the customer's business processes be modelled in order to provide an appropriate level of abstraction for the Capability System Model, so that it is suitable to be used as the major artefact to cross the acquisition boundary.

[4] The FIC is the standard list for consideration of what is required to generate Defence capability, comprising *organisation*, *personnel*, *collective training*, *major systems*, *supplies*, *facilities*, *support*, and *command & management*.

Specifically, the workshop will address the following three questions:

Question 1: What information and processes currently described in text-based systems acquisition (TBSA) (i.e. in the OCD and FPS) would still be required to be included in some way in the MODEL which is the basis of model-based systems acquisition (MBSA)?

Question 2: How can each information/process be modelled in MBSA, and how would that be different to TBSA?

Question 3: What processes/information would be modelled in MBSA that do not exist in TBSA?

Facilitator Biography

Dr Michael John (Mike) Ryan is a Senior Lecturer with the School of Engineering and Information Technology, University of New South Wales, at Canberra. He holds Bachelor, Masters and Doctor of Philosophy degrees in electrical engineering as well as a Graduate Diploma in Management Studies. In addition, he has completed two years formal project management training in the United Kingdom. For the first seventeen years of his career he held a number of communications engineering, systems engineering, project management, and management positions in the Australian Army. Since joining UNSW, he has become an internationally recognised expert in systems engineering and requirements engineering, and has made a number of important contributions to the field.

Dr Ryan regularly consults in the fields of systems engineering, requirements engineering, communications and information systems architectures, project management, and technology management including work for the 2004 Athens Olympic Games, the Department of Defence, other government departments, defence industry, and other industry.

Dr Ryan conducts courses in systems engineering and requirements engineering as well as in the more-focused application in Defence acquisition, particularly in the development of the capability development documents (CDD) that guide acquisition in the Australian Department of Defence. He is the principal architect of the Master of System Engineering program run by the University of New South Wales in Canberra, creating the program structure and preparing the appropriate documentation for program approval. He also developed three of the four core courses in that program and is currently delivering two of the courses (systems engineering and requirements engineering).

He is a Fellow of the Institution of Engineers, Australia; a senior member of the Institute of Electrical and Electronic Engineers; a member of the International Council on Systems Engineering; and a member of the Systems Engineering Society of Australia (in which he also serves on the management committee as the academic representative and the chair of the annual conference). He is currently the Chair of the Requirements Working Group in the International Council on Systems Engineering (INCOSE).

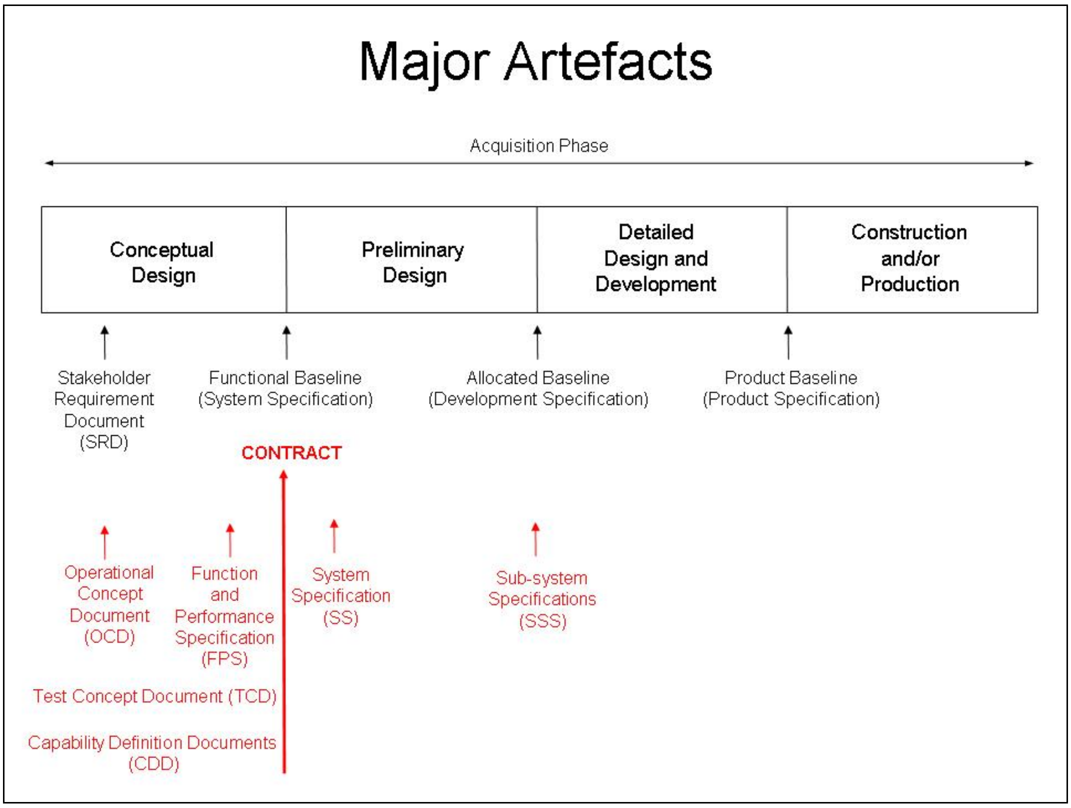
Dr Ryan is the Editor-in-Chief of the international journal, *Journal of Battlefield Technology*, and is the author or co-author of nine books and three book chapters and over 100 technical papers and reports. He is a principal author of the *Guide for Writing Requirements*, recently published by INCOSE and is one of the authors of the revised edition of the *INCOSE Systems Engineering Handbook* (which is the basis of accreditation of systems engineers internationally).

Workshop Presentation and Outcomes

What is a Capability System Model?

- Question 1: Since text-based systems acquisition (TBSA) doesn't work, what information and processes currently described in TBSA (in the OCD and FPS) would still be required to be included in some way in the MODEL which is the basis of model-based systems acquisition (MBSA)?
- Question 2: How can each information/process be modelled in MBSA, and how would that be different to TBSA?
- Question 3: What processes/information would be modelled in MBSA that do not exist in TBSA?

Systems Acquisition in Defence



OCD Template

1. SCOPE

1.1 Capability Identification

1.2 Document Purpose & Intended Audience

1.3 Justification for Capability

1.4 System Boundary and Acquisition Assumptions

1.5 Key Timeframes for Capability

2. DEFINITIONS AND REFERENCED DOCUMENTS

2.1 Referenced Documents

2.2 Glossary of Terms

3. SOLUTION-INDEPENDENT CAPABILITY NEEDS

3.1 Mission Overview

3.2 Operational Policies and Doctrine

3.3 Capability System End-user classes

3.4 Summary of Operational Scenarios

3.4.1 Common Scenario Attributes

3.4.2 Scenario 1 - Scenario Title

3.4.2.1 Summary of Situation

3.4.2.2 Summary of Military Response

3.4.2.3 Summary of Operational Needs

3.4.3 Scenario N - Scenario Title

3.5 Summary of Consolidated Operational Needs

3.6 Solution-class-Independent Constraints

4. EXISTING SYSTEM

4.1 Existing System Overview

4.2 Existing System Operational Capability Comparison

4.3 Existing System Internal Shortcomings

4.4 Existing System Planned or Active Upgrades

4.5 Existing System Internal User classes

4.6 Existing System Internal Functionality

4.7 Summary of Existing System Internal Scenarios

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OCD Template

5. SOLUTION-CLASS DESCRIPTION

5.1 Materiel System Description

5.2 Mission System Architecture

5.3 Materiel System Interfaces

5.4 Materiel System Internal User classes

5.5 Materiel System Functionality and Performance

5.6 Materiel System Spt Concepts and Reqts

5.7 Materiel System Constraints

5.8 Materiel System Evolution & Tech F'cast

5.9 Summary of Internal Scenarios

5.9.1 Internal Scenario 1

5.9.1.1 Summary of Situation

5.9.1.2 Summary of Process Flows Interactions

5.9.1.3 Summary of System Reqts

5.9.2 Internal Scenario 2 - Scenario Title

5.9.3 Internal Scenario N - Scenario Title

6. CONSOLIDATED FUNDAMENTAL INPUTS TO CAPABILITY (FIC) REQUIREMENTS

6.1 FIC Related Guidance

6.2 Major Systems FIC Element Requirements

6.3 Facilities and Training Areas FIC Element Requirements

6.4 Support FIC Element Requirements

6.5 Supplies FIC Element Requirements

6.6 Organisation FIC Element Requirements

6.7 Command and Management FIC Element Requirements

6.8 Personnel FIC Element Requirements

6.9 Collective Training FIC Element Requirements

6.10 FIC Impacts on Supporting Capabilities

6.11 Summary of Overall FIC Responsibilities

6.12 FIC Development Forecast

DID-ENG-DEF-OCD-V2.0

FPS

- Specifies formal requirements for the System.
- Provides the basis for design and qualification testing of the system.
- Provides the vehicle for the capture of formal, verifiable and unambiguous requirements, 'distilled' from the OCD.
- Is intentionally written using formal language, with all requirements in the FPS traceable to needs in the OCD.

CDD Guide v2.0

FPS Template

Section 1 – Scope
1.1 – Identification
1.2 – System Overview
1.3 – Document Overview
Section 2 – Applicable Documents
Section 3 – Requirements
3.1 – Missions
3.2 – System Boundaries and Context
3.3 – Required States and Modes
3.4 – System Capability Requirements
3.5 – Availability
3.6 – Reliability
3.7 – Maintainability
3.8 – Deployability
3.9 – Transportability
3.10 – Environmental Conditions
3.11 – Electromagnetic Radiation
3.12 – Architecture, Growth and Expansion
3.13 – Safety
3.14 – Environmental Impact Requirements
3.15 – Useability and Human Factors
3.16 – Security and Privacy
3.17 – Adaptation Requirements
3.18 – Design and Implementation Constraints
3.19 – System Interface Requirements
Section 4 – Precedence and Criticality of Requirements
Section 5 – Verification
Section 6 – Requirements Traceability
Section 7 – Notes

Workshop Outcomes

⑩ What is a (capability) model?

- An algorithm is a model
- Level of abstraction
- Conceptual model to executable model
- **Non functional requirements / constraints**
- **Expression of knowledge**
- **Behaviour of a system** (including over time)
- **Describes the structure of the environment and interfaces**
- **Visible FIC elements including the support system**
- **Performance and boundaries of execution**
- **Describes the problem**
- **Captures the requirements**
- **Fit-for-purpose representation of the capability**
- ***Structured and traceable information***

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Workshop Outcomes

➉ What is the purpose of the (capability) model?

- Develop shared understanding
- Enables / Documents decision making
- Knowledge transfer
- To go to contract / tender
- Communicate the capability of a system to a sufficient level of fidelity (reduce risk)
- Validation baseline
- Integration of knowledge from lower level models
- To describe the relationships with the capability of your other systems

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10. WORKSHOP 2: MBSE Practices Across the Contractual Boundary

Quoc Do[1] and Jon Hallett[2]
[1]Defence Systems Innovation Centre (DSIC) and [2]Deep Blue Tech

Abstract

Systems engineering practice is progressively migrating to Model-Based Systems Engineering (MBSE) practice as evidenced through the contributions to the DSTO MBSE Symposium (2011), INCOSE MBSE International Workshop (2012) and ongoing activities in various Australian organisations such as DSTO[5], Deep Blue Tech[6], Air Warfare Destroyer[7], Aerospace Concepts[8], Raytheon[9], and DSIC[10,11]. Furthermore, MBSE is gaining momentum within the Australian Department of Defence. In particular, the SEA 1000, LAND 400, and LAND 19 (Phase 7) projects are adopting an MBSE approach for the capability system definition.

However, to date MBSE has only been adopted on an "Ad-hoc" basis (aka "model-supported engineering"). In other words, models are used to support the system engineering activities at distinct phases, rather than being evolved and matured throughout the system lifecycle. One of the key impediments is the reliance by all parties on the use of documents at the contractual interface between the acquirer and the provider, as illustrated in **Figure 1**.

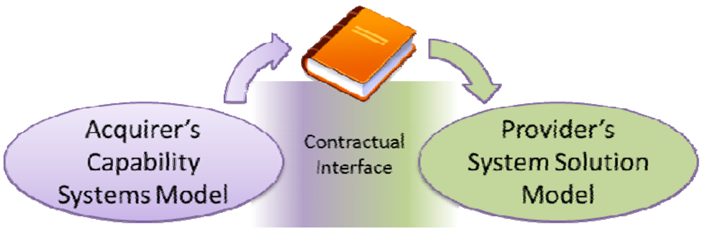

Figure 1: Contractual Interface

As a result, in the defence context, "*above-the-line*" (acquirer) capability models are required to produce a Capability Definition Document (CDD) set and other related artefacts. These

[5] Robinson, K., et al. *Demonstrating Model-Based Systems Engineering for Specifying Complex Capability*, in Systems Engineering Test and Evaluation (SETE) 2010 Adelaide, Australia
[6] Pearce, P., *Model-Based Systems Engineering and Its Application to Submarine Design*, in Submarine Institute of Australia Science, Technology and Engineering Conference 2011, Adelaide, Australia
[7] Mays, R., *Deploying a SysML MBSE Environment - Lessons Learned from the SEA 4000 - Air Warfare Destroyer Program*, in DSTO MBSE Symposium 2011, Adelaide, Australia
[8] Harvey, D., et al., *Document the Model, Don't Model the Document*, in INCOSE International Symposium 2012, Rome, Italy
[9] Saunders, S., *Does a Model Based Systems Engineering Approach Provide Real Program Savings? - Lessons Learnt*, in DSTO MBSE Symposium 2011, Adelaide, Australia
[10] Do, Q., et al., *Requirements for a Metamodel to Facilitate Knowledge Sharing between Project Stakeholders*, in 10th Annual Conference on Systems Engineering Research (CSER 2012)2012, Missouri, US
[11] Do, Q. and S. Cook, *An MBSE Case Study and Research Challenges*, in 22nd Annual International Symposium of INCOSE2012, INCOSE, Rome, Italy

documents are then provided to potential prime contractors (providers) who then interrogate them to produce their own systems model. This is an inefficient process and there is a high likelihood of errors and unwanted artefacts being introduced into the process.

One solution would be to pass the capability system models through the contractual interface and integrate them to the provider's system solution model. In order to address this issue, the workshop aims to discuss and surface the key issues and challenges inherent in utilising a single MBSE representation in a competitive tender environment.

The workshop discussion will be limited to the Request For Tender (RFT) defence contracting model and will be focussed on the following areas (but not limited to):

1. What classes of information in the Acquirer's Capability System Model should be disclosed to the Provider?
2. What classes of information in the Provider's System Solution Model should be disclosed to the Acquirer?
3. How should the two models be interfaced?
4. Metamodels that could underpin items 1-3
5. Model-based tender evaluation by the acquirer
6. Model-based RFT evaluation by the provider
7. Legal framework and IP issues.

Facilitator Biographies

Dr Quoc Do is currently a Research Lead – MBSE, at the Defence Systems Innovation Centre (DSIC), and a Research Fellow at the Defence and Systems Institute (DASI), University of South Australia. He completed his BEng, MEng and PhD all at the University of South Australia. His research interests are in the areas: 1) systems engineering, including systems integration of COTS/MOTS components, Model-Based Systems Engineering (MBSE), systems engineering of autonomous systems, and systems of systems; and 2) domain-specific engineering research, including autonomous systems, vision systems, data fusion, artificial intelligent, agent-based modelling, and Data Distribution Services (DDS). In addition, he has been actively involving in systems engineering professional societies, and currently the Deputy President of the Systems Engineering Society of Australia (SESA), and Associate Director for Technical Review of INCOSE. He is also the Editor of the International Journal of Intelligent Defence Support Systems (IJIDSS).

Jonathan Hallett is the Systems Engineering Team Leader at Deep Blue Tech (DBT) and has over 27 years' experience in the Maritime Defence Arena.

A major focus of Jon's work at DBT involves ensuring understanding and consistency across the design team through process, practise, tools and training. Jon leads the requirements development effort within DBT working with both retired submariners and DBT's engineers. He provides both the co-ordination and interpretation of the needs of both the Operator Community and the Design Engineers to ensure that they are understood and translated into unambiguous requirements for the design team to work with.

Immediately prior to joining DBT, Jon was a Consultant to the Finnish Navy MCMV 2010 project where he supported the Navy in their requirements definition, design reviews and shipbuilder/contractor reviews leading up to and during construction of three new Mine Countermeasures Vessels.

Before this, Jon worked for QinetiQ (and its predecessors) in the Underwater Warfare area. He occupied roles such as Deputy Head of Science and Engineering – Underwater Systems, Business Group Manager – Underwater Warfare and Studies, Capability Leader – Detection Systems and Team Leader – Mine Sweeping Systems. During this time, Jon led and participated in numerous concept studies at business, platform and system level across the Underwater Warfare spectrum of activities. He was the QinetiQ Technical Representative in the UK MoD's Mine Countermeasures Equipment (MCME) IPT, Sea Division representative on the QinetiQ Systems Engineering Practitioners Forum and has represented the UK on a NATO Mine Warfare Project Group and Joint Research Programme.

Workshop Presentation and Outcomes

Background

- Systems engineering practice is progressively migrating to Model-Based Systems Engineering (MBSE)
- MBSE has only been adopted on an "Ad-hoc" basis (aka "model-supported engineering")
- Document-based knowledge transfer / traceability

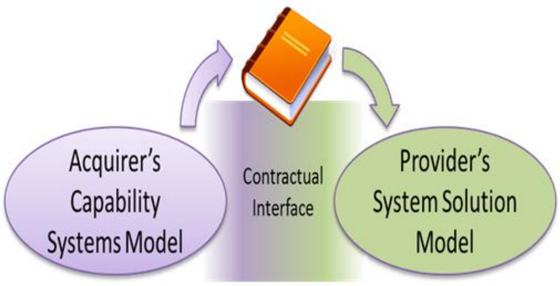

Figure 1: Contractual Interface

Assumptions

- Assuming that the Model-Based Acquisition is feasible and can be divided into the following phases:
- Model-Support Acquisition – Reflect current practices where models are used to support various engineering activities, including the production of key documents for contractual purposes.
- Model-Integrated Acquisition – Models form part of the contractual artefacts but as secondary or complementary artefacts.
- Model-Centric Acquisition – Models are the primary artefacts (with the capability to generate required documentation).

Discussion – Part 1 (45mins)

- Parallel Groups Discussion (1/2):
  - Qn 1. What classes of information in the Acquirer's Capability System Model should be disclosed to the Provider?
  - Qn 2. What classes of information in the Provider's System Solution Model should be disclosed to the Acquirer?
- Whole Group Discussion (1/2)
  - Report from each group for Qn1 and Qn2.
  - Qn.3. How should the two models be interfaced?

5min Break!

Discussion - Part 2 (45 mins)

- Parallel Groups Discussion (1/2):
  - Group 1:
    - Qn 4. Metamodels that could underpin items 1-3 ?
    - Qn 5. Model-based tender evaluation by the acquirer ?
  - Group 2:
    - Qn 6. Model-based RFT evaluation by the provider
- Whole-Group Discussion (1/2)
  - Report from each group for Qn 4, 5 and 6.
  - Qn.7. What are the impediments to achieving the long term goal (i.e. Legal framework and IP issues)?

End!

Workshop Outcomes

- Phased approach discussed:
  - **Model-Support Acquisition** – Reflect current practices where models are used to support various engineering activities, including the production of key documents for contractual purposes.
  - **Model-Integrated Acquisition** – Models form part of the contractual artefacts but as secondary or complementary artefacts.
  - **Model-Centric Acquisition** – Models are the primary artefacts (with the capability to generate required documentation).

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Workshop Outcomes

- What classes of information in the Acquirer's Capability System Model should be disclosed to the Provider?
  - What <u>wouldn't</u> we pass across in model form?
    - Costing information, internal management information
    - Sensitive information (particularly prior to contract)
    - Information that does not make sense in a model
  - Functional model
    - Possible for iterative approach between government and industry
    - Issue of how approvals of model will take place vs a document-based approach
  - Rationale for performance figures and essential/desirable etc.
  - Standards
    - How to specify which details are relevant and testing against these
    - If conversion into model is sensible or useful
  - Support concept, test and evaluation information

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Workshop Outcomes

- What classes of information in the Provider's System Solution Model should be disclosed to the Acquirer?
  - What wouldn't be passed?
    - Lower-level detail risk and cost
  - System behaviour and Measures of Performance
  - Assumptions, rationales, applicable standards
  - Test plans and test cases
  - Technical forecast and resulting risks, Technical Integrity Risk
  - Support system model
  - Anything as specified by acquirer – when it makes sense to be in a model
  - IP might not be a problem at bid-time
    - Systems model should be abstract enough to avoid this
    - More detailed model would contain the IP information

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DSTO

Workshop Outcomes

- How should the two models be interfaced?

- Issues:
  - Need a metamodel defined by government in order to answer this

  - Industry may or may not be able to deal with standards or tools, especially international bidders

  - Current interfacing standards lacking, these need to catch up before they can be mandated

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DSTO

Workshop Outcomes

- Questions still to be addressed in the future:
  - Metamodels that could underpin items 1-3 ?
  - Model-based tender evaluation by the acquirer ?
  - Model-based RFT evaluation by the provider
  - What are the impediments to achieving the long term goal (i.e. Legal framework and IP issues)?

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11. KEYNOTE 2 : Rebuilding the Tower of Babel – Better Communication with Standards

Matthew Hause
Co-chair of the UPDM group, OMG

Abstract

The book of Genesis tells the story of how the peoples of the earth came together to build an enormous tower. To confound them in their task, God changed the languages of the different groups of people so that they were unable to communicate. Since they could not coordinate their efforts, the project was abandoned and the different groups dispersed throughout the world.

The same problem exists today in the world of Architecture Frameworks. Although they express similar concepts, interchange between the different frameworks is awkward at best, time consuming, and leads to misunderstanding and miscommunication. This lack of communication was highlighted in a recent report on the conflict in Afghanistan, where the lack of interchange of architectures was cited as a limiting factor in coalition efforts and may have contributed to loss of life.

This presentation will assess the current situation, examine international efforts to solve it, and identify future challenges. This will include:

- The role of standards for collaboration and communication
- Standards and standards organisations
- The Object Management Group (OMG)
- A brief history of Military Architectural Frameworks
- The interoperability problems of frameworks
- The Unified Architecture Framework (UAF) effort
- Using reference architectures to define a common conceptual "dictionary"
- Systems engineering, acquisition, and process
- Vertical and horizontally complementary emerging standards
- Future problems and potential solutions

Presenter Biography

Matthew Hause is Atego's Chief Consulting Engineer, the co-chair of the UPDM group (Unified Profile for DoDAF/MODAF) and a member of the Object Management Group (OMG) SysML specification team. He has been developing multi-national complex systems for almost 35 years. He started out working in the power systems industry and has been involved in military command and control systems, process control, communications, Supervisory Control And Data Acquisition (SCADA), distributed control, and many other areas of technical and real-time systems. His roles have varied from project manager to developer. His role at Atego includes mentoring, sales presentations, standards development and training courses. He has written a series of white papers on architectural modeling, project management, systems engineering, model-based engineering, human factors, safety critical systems development, virtual team management, systems development, and software development with UML, SysML and Architectural Frameworks such as DoDAF and MODAF. He has been a regular presenter at INCOSE, the IEEE, BCS, the IET, the OMG, DoD Enterprise Architecture and many other conferences. Matthew studied Electrical Engineering at the University of New Mexico and Computer Science at the University of Houston, Texas. In his spare time he is a church organist, choir director and composer.

Presentation

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Agenda

- Barriers to communication and collaboration
- The interoperability problems of frameworks
- Standards and standards organisations
- A brief history of Military Architectural Frameworks
- Working Towards a Common Framework
- Exchange of Architecture Data
- Using Reference Architectures for a common conceptual "dictionary"
- Systems engineering, acquisition, and process
- Vertical and horizontal complementary standards
- Future Problems and solutions

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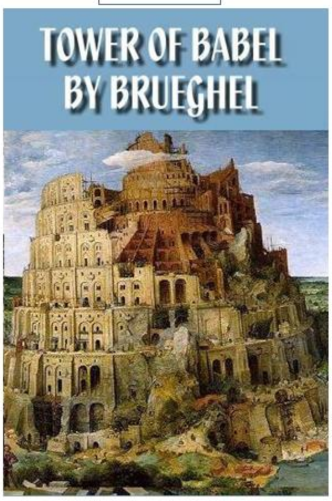
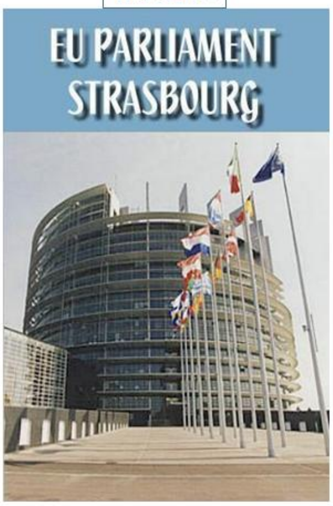
The Tower of Babel – A Communications Fable for our Time

Ancient



Modern



Does this solve the problem?

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European Union Parliament Translation Services

- The EU has 20 recognised languages, 380 language permutations and an annual interpreting and translation bill of €1bn.
- EU institutions currently require around 2,000 written-text translators. They also need 80 interpreters per language per day, half of which operate at the European Parliament.
- From 2007 Irish MEPs have been able to speak in the chamber of the European Parliament in the Irish language with interpretation, though no more than five Euro-MPs have the fluency to do so.
- Catalans and Basques have won more limited language rights. Welsh speakers are stepping up demands.
- Languages include Maltese despite the fact that Malta is largely Anglophone and has just 397,000 citizens.

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USA/UK: Two Countries Separated by a Common Language

- Even speaking the same language doesn't always help. Picture this:
  - A man wearing a vest, pants, and a pair of suspenders.

So, if communication is hard with spoken language, are models the answer?

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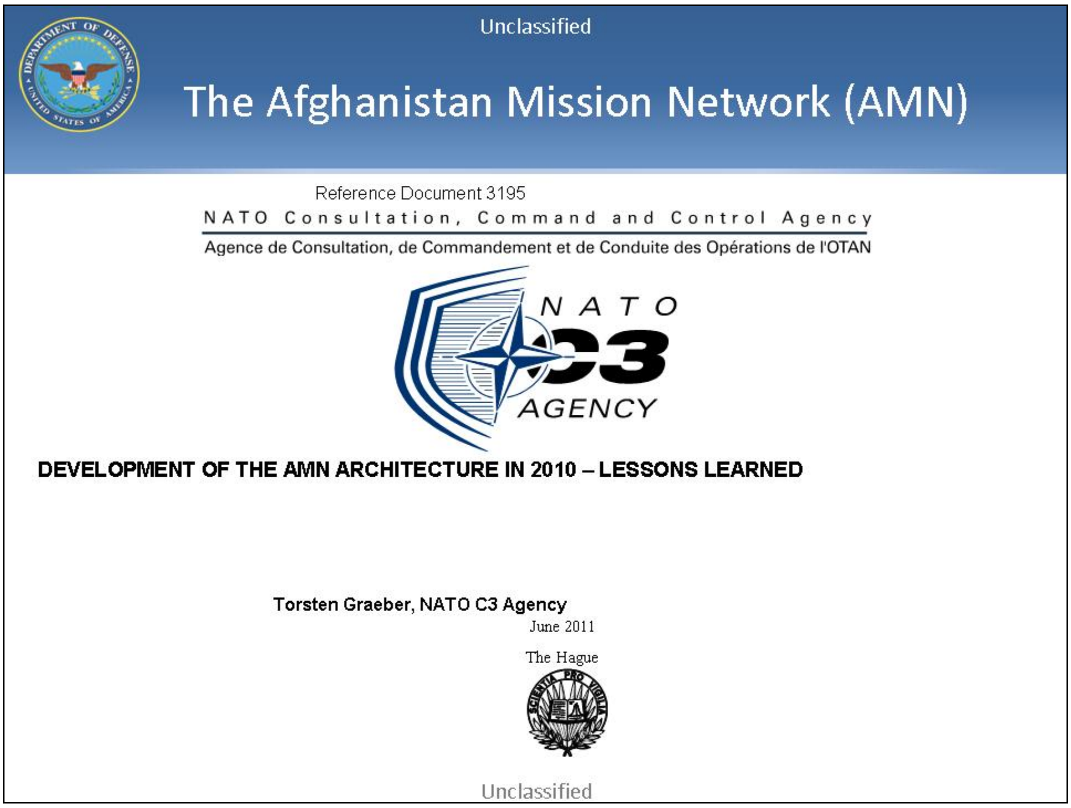
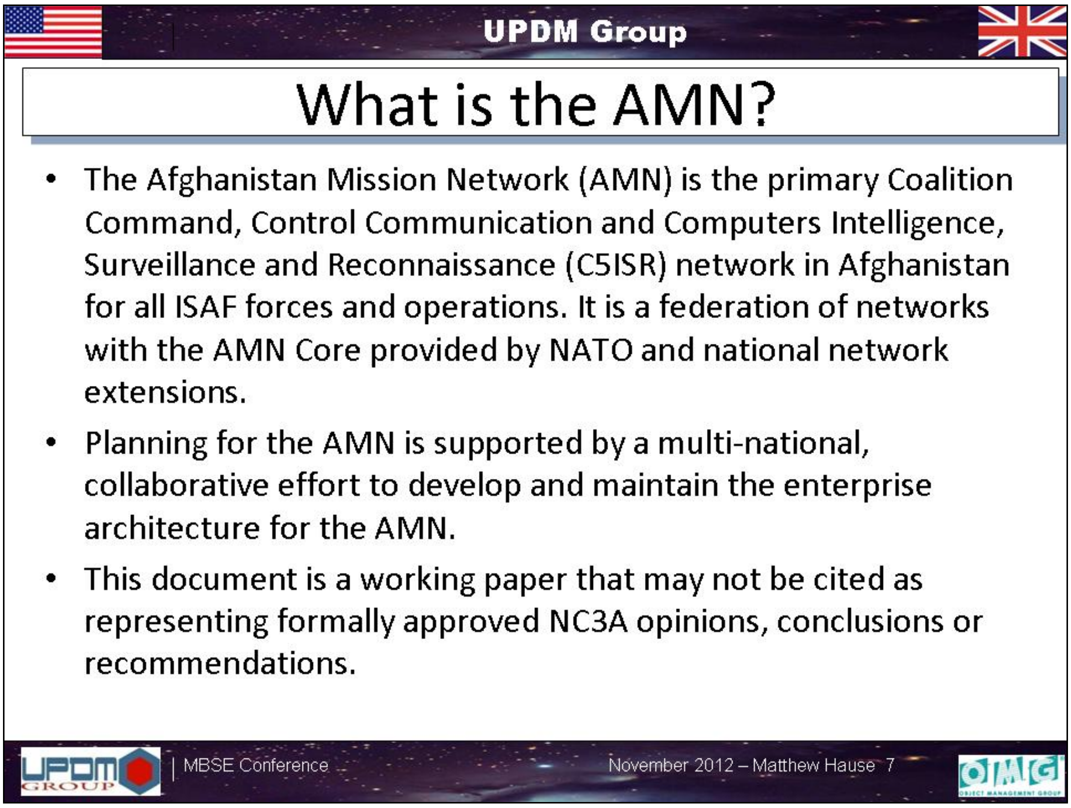

Unclassified
The Afghanistan Mission Network (AMN)
Reference Document 3195
NATO Consultation, Command and Control Agency
Agence de Consultation, de Commandement et de Conduite des Opérations de l'OTAN
NATO C3 AGENCY
DEVELOPMENT OF THE AMN ARCHITECTURE IN 2010 – LESSONS LEARNED
Torsten Graeber, NATO C3 Agency
June 2011
The Hague
Unclassified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What is the AMN?
• The Afghanistan Mission Network (AMN) is the primary Coalition Command, Control Communication and Computers Intelligence, Surveillance and Reconnaissance (C5ISR) network in Afghanistan for all ISAF forces and operations. It is a federation of networks with the AMN Core provided by NATO and national network extensions.
• Planning for the AMN is supported by a multi-national, collaborative effort to develop and maintain the enterprise architecture for the AMN.
• This document is a working paper that may not be cited as representing formally approved NC3A opinions, conclusions or recommendations.
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AMN Issues (1)

- In 2010, there was no proper governance structure for the AMN as a whole.
- Likewise there was no governance for the development of the AMN architecture.
- The development of the architecture was primarily coordinated through the AWG consisting of the architects of the nations participating in the AMN.
- This AWG usually received ad hoc tasking from different stakeholders involved in the development of the AMN without clear leadership defining the goals and deliverables upfront.
- As a direct result of this missing governance several issues arose that had a negative impact on the architecture development work.

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AMN Issues (2)

- These issues included:
  - Different expectations on content and usage of the architecture leading to ever changing requirements and deliverables
  - No enforcement of the architecture during implementation
  - Usage of different architecture frameworks
  - Usage of different architecture tools.
  - No interchange between the tools
- In late 2010, a governance structure for the AMN was endorsed by Chief Of Staff SHAPE and the AWG was included in this governance structure. As a direct consequence, the situation regarding clearer expectations, deliverables and enforcement of architecture has been improved in 2011.
- **However, as the architects are sponsored by their respective nations they have to implement national policies and requirements, so that improvements regarding the usage of a single framework and tool are not to be expected.**

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AMN Recommendations

- Recommendation 1
  - Before starting, establish the governance structure.
- Recommendation 2
  - Ensure availability of a common infrastructure allowing remote access to a single repository
- Recommendation 6
  - Harmonize national and NATO policies related to architecture development and reference architectures.
- Recommendation 16
  - Develop common reference models
- Recommendation 18
  - Standardize on one tool and a single repository. Synchronization is expensive as is training.
- Recommendation 19
  - Develop a formal exchange mechanism for data

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Standards Are Important

- **Great Baltimore Fire of 1904**
- **Response from Philadelphia, Washington, New York, Virginia, Atlantic City… hundreds of firefighters**
- **Burned for two days, 140 acres**
- **Why?**

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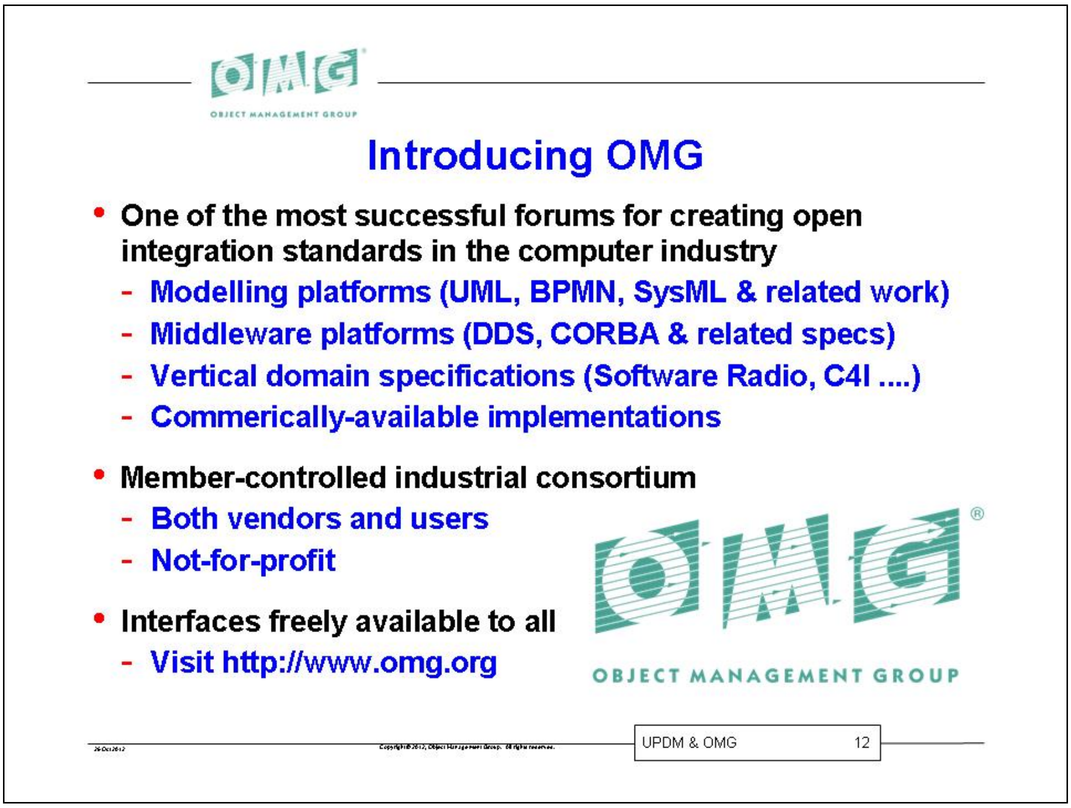
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Introducing OMG
One of the most successful forums for creating open integration standards in the computer industry
- Modelling platforms (UML, BPMN, SysML & related work)
- Middleware platforms (DDS, CORBA & related specs)
- Vertical domain specifications (Software Radio, C4I ....)
- Commerically-available implementations
Member-controlled industrial consortium
- Both vendors and users
- Not-for-profit
Interfaces freely available to all
- Visit http://www.omg.org
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Who Are OMG?
Atego
ASC
Boeing
CA Technologies
Canadian DnD
Citigroup
Cognizant
CSC
US DoD/DISA
EADS
FICO
Firestar Software
Fujitsu
Hewlett Packard
Hitachi
HL7
IBM
JARA
Lockheed Martin
Mayo Clinic
Microsoft
MITRE
British MOD
National Archives
NEC
NEHTA
NIST
No Magic
Northrop Grumman
NSWC & NUWC
OASIS
ODNI
Oracle
PTC
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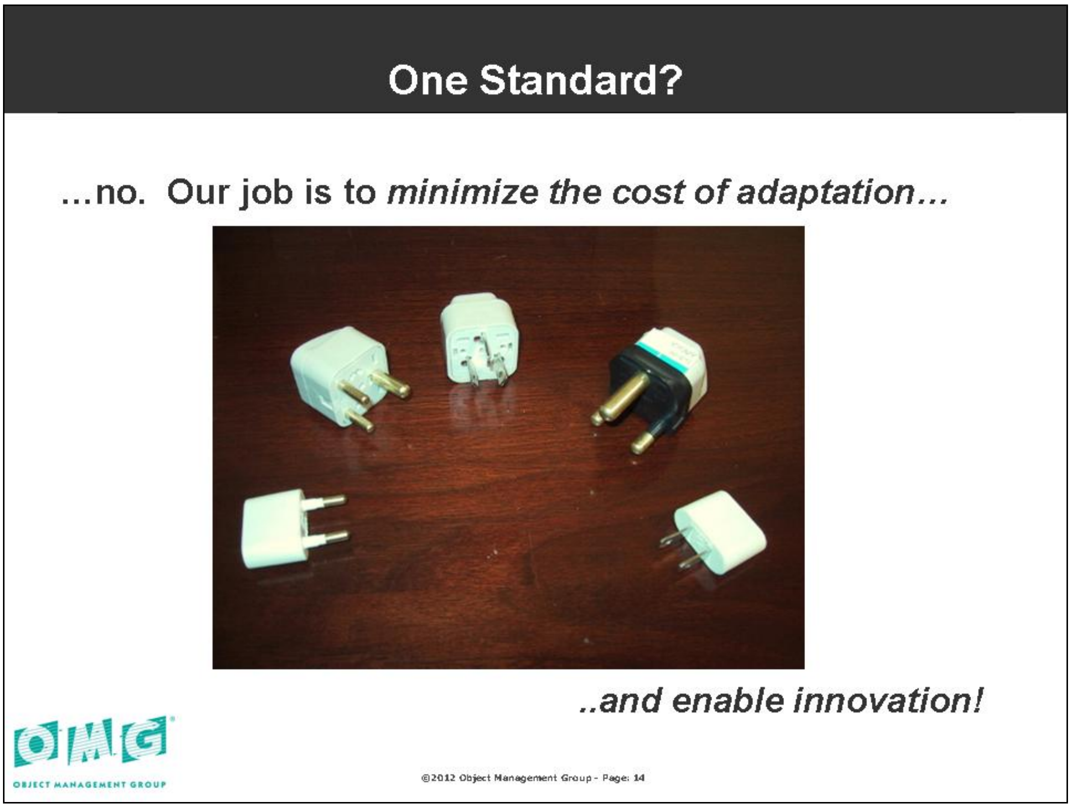
One Standard?
…no. Our job is to minimize the cost of adaptation…
..and enable innovation!
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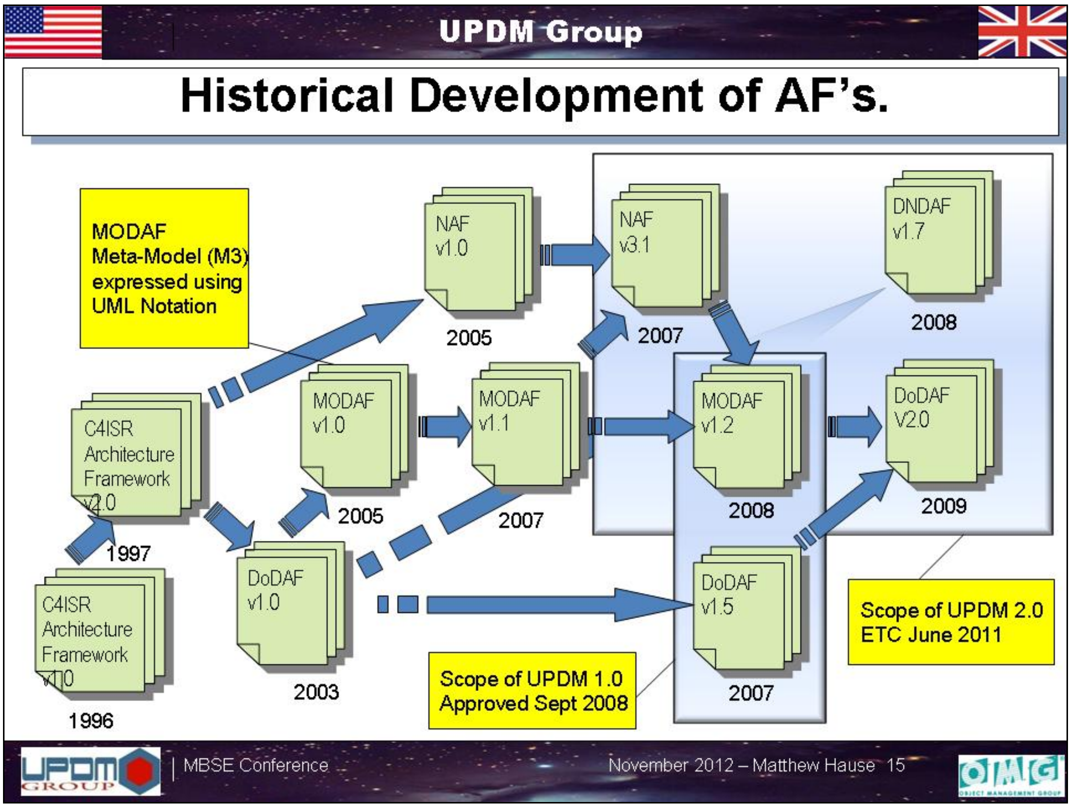
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Historical Development of AF's.
MODAF Meta-Model (M3) expressed using UML Notation
NAF v1.0
2005
NAF v3.1
2007
DNDAF v1.7
2008
C4ISR Architecture Framework v2.0
1997
MODAF v1.0
2005
MODAF v1.1
2007
MODAF v1.2
2008
DoDAF V2.0
2009
C4ISR Architecture Framework v1.0
1996
DoDAF v1.0
2003
DoDAF v1.5
2007
Scope of UPDM 1.0 Approved Sept 2008
Scope of UPDM 2.0 ETC June 2011
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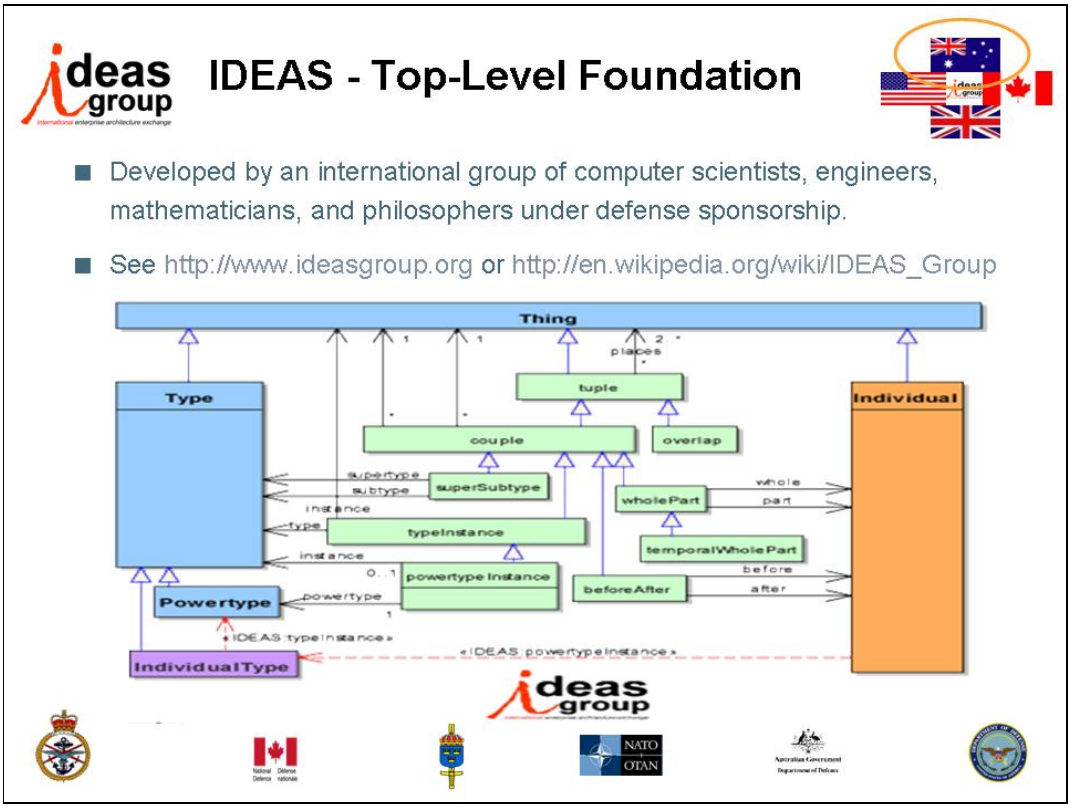
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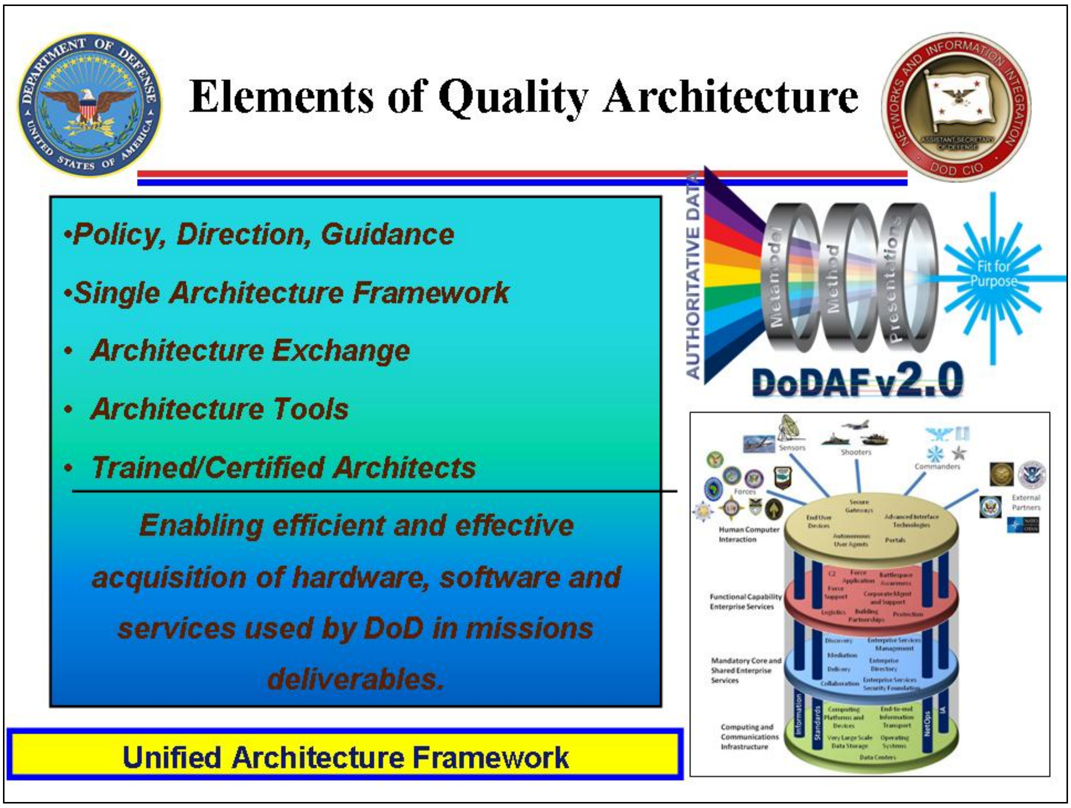
Developed by an international group of computer scientists, engineers, mathematicians, and philosophers under defense sponsorship.
See http://www.ideasgroup.org or http://en.wikipedia.org/wiki/IDEAS_Group
Thing
places
tuple
Type
Individual
couple
overlap
supertype
subtype
superSubtype
whole
part
wholePart
instance
type
typeInstance
temporalWholePart
instance
powertypeInstance
before
after
beforeAfter
Powertype
powertype
«IDEAS:typeInstance»
«IDEAS:powertypeInstance»
IndividualType
ideas group
NATO OTAN


Elements of Quality Architecture
•Policy, Direction, Guidance
•Single Architecture Framework
• Architecture Exchange
• Architecture Tools
• Trained/Certified Architects
Enabling efficient and effective acquisition of hardware, software and services used by DoD in missions deliverables.
Unified Architecture Framework
AUTHORITATIVE DATA
Metamodel
Method
Presentations
Fit for Purpose
DoDAF v2.0

Unclassified

Unified Architecture Framework NATO Architecture CaT Introduction

Mr. Walt Okon
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DoD Chief Information Officer Office
Architecture and Interoperability Directorate
walt.okon@osd.mil

10-11 September 2012

Office of the Chief Information Officer

Unclassified

Unclassified

4.1 ARCHITECTURE FRAMEWORKS

- **4.1.2 Observations [Need for a Unified Architecture Framework]**
- **Differences in DoDAF, MODAF, and NAF make it difficult to match the meta-model one to one.**
  - **some of the concepts in the frameworks have the same name but different definitions, i.e. different semantics.**
- **Difficult to cross-walk the concepts between the different frameworks leads to miscommunication between architects using different frameworks.**

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Unified Architecture Framework

Unified Architecture Framework Strategic Direction

•Move towards a Single Architecture Framework to achieve Interoperability
•Development of the AMN architecture in 2010
•Development of Unified Profile for DoDAF and MODAF (UPDM) Versions 1.0, 2.0, and 3.0
•Meeting at Object Management Group (OMG) March 2012
•Ideas Meeting in June 2012
•Plan for NATO CAT workshop 10/11 Sept 2012

Launchpad for Unified Architecture Framework (UAF)

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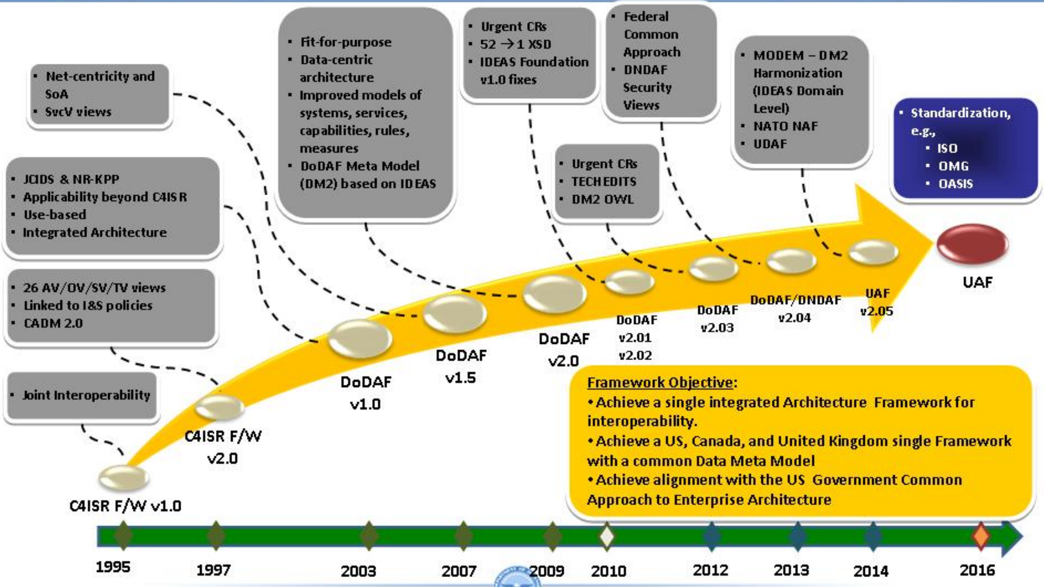
Architecture Framework Convergence Vision



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The Unified Profile for DoDAF and MODAF

- UPDM is a standardized way of expressing DoDAF and MODAF artefacts using UML and SysML
  - UPDM is NOT a new Architectural Framework
  - UPDM is not a methodology or a process
  - UPDM implements DoDAF 2.0, MODAF & NAF
- UPDM was developed by members of the OMG with help from industry and government domain experts.
- UPDM is a DoD mandated standard and has been implemented by multiple tool vendors.
- UPDM is a proof of concept of the UAF
- Future versions of UPDM will implement the UAF

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Data Exchange Case Study: CAD (1)

- Computer Aided Design (CAD) data exchange involves a number of software technologies and methods to translate data from one Computer-aided design system to another CAD file format. This PLM technology is required to facilitate collaborative work (CPD) between OEMs and their suppliers.
- The main topic is with the translation of geometry (wireframe, surface and solid) but also of importance is other data such as attributes; metadata, assembly structure and feature data.
- There are basically three methods of transferring data from one CAD system to another.
  - Direct CAD system export/import
  - Direct 3rd party translators.
  - Intermediate data exchange formats

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Data Exchange Case Study: CAD (2)

- Intermediary Format.
  - Some by standards organisations
  - Others are private and regarded as quasi industry standards.
- Examples
  - STEP – ISO 10303, a replacement for IGES and VDA-FS with the CAD specific parts: STEP AP203 and AP214: Mechanical CAD systems
    - STEP AP210: CAD systems for printed circuit board
    - STEP AP212: CAD systems for electrical installation and cable harness
    - STEP-NC AP238: CAD, CAM, and CNC machining process information
    - STEP AP242, Managed Model-Based 3D Engineering – the merging of the two leading STEP application protocols, AP 203 and AP 214
  - Others: IGES, VDA-FS, DXF, Parasolid XT, JT Open, DRG, etc.
- In short: multiple incompatible standards offering partial solutions.

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DoDAF Physical Exchange Specification (PES) – A Solution?

- PES is a direct translation of a DoDAF model into XML based on the data in the DoDAF 2 Data Dictionary and Viewpoint Mappings
- Proprietary standard, developed, owned and maintained by the DoD.
- New versions of DoDAF means new versions of PES automatically generated from the DM2.
  - No tools to support backwards compatibility of a means of converting between different versions of the PES.
  - No formal verification and validation of the DM2.
- Currently no significant level of support within tools.
- Tests of complete/interoperable implementation of PES across tools have not been performed nor have interchange standards been defined.

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DoDAF Physical Exchange Specification (PES) – A Solution?

- Parsing a PES file will be problematic
- In the DM2 there is only one definition of activity. Is this:
  - a project activity?
  - a system activity?
  - a service activity?
  - an operational activity?
  - All of them?
- How does one know to which model the activity belongs?
- The PES will need significant work before it can be used to successfully interchange models.
- Most important, it will not solve the interchange problem between DoDAF and MODAF models.
- The DoD is considering RDF as an alternative.

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Modelling Tool Interoperability

- **OMG publishes standard for MOF model interchange**
  - **XML Metadata Interchange (XMI)**
  - **UML, SysML, UPDM all based on MOF models**
- **Sadly, publishing standard doesn't guarantee separate good-faith implementations can interchange models**
  - **Tiny ambiguities & programming errors kill interoperability**
- **Multi-vendor testing drives out bugs, assures interoperability**
  - **OMG Model Interchange Working Group compiles tests**
  - **Vendors run tests, fix their tools or file spec. bug reports**
  - **UPDM OV-2 interchange demonstration at April 2012 DoD Enterprise Architecture Conference**
  - **Result: assures tool interoperability & model longevity**

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Reference Architectures – A common dictionary

- Provides a template solution for an architecture for a particular domain.
- Provides a common vocabulary to discuss implementations
  - Stresses commonality.
- Defines functions and interfaces and interactions
- Can be defined at different levels of abstraction.
- Set of patterns of successful implementations.
  - Shows how to compose these parts together into a solution.
  - Will be instantiated for a particular domain or for specific projects.
- Accelerates delivery through the re-use of an effective solution and provides a basis for governance to ensure the consistency and applicability of technology use.
- Dependent on a common data/interchange format, storage and distribution capability, configuration management, etc.

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Architecture Reference Models

- The intent of this Australian Government Architecture (AGA) framework is to assist in the delivery of more consistent and cohesive services to citizens and support cost-effective delivery of Information and Communications Technology (ICT) services by government, providing a framework that:
  - provides a common language: provides a common language for agencies involved in the delivery of cross-agency services
  - enhances collaboration: supports the identification of duplicate, re-usable and sharable services
  - assists in describing and analysing ICT investments: provides a basis for the objective review of ICT investments by government
  - assists in transforming Government (citizen-centric, results-oriented, market-based): enables more cost-effective and timely delivery of ICT services through a repository of standards, principles and templates that assist in the design and delivery of ICT capability and, in turn, business services to citizens.

Australian Government Architecture Reference Models, August 2011 Version 3.0

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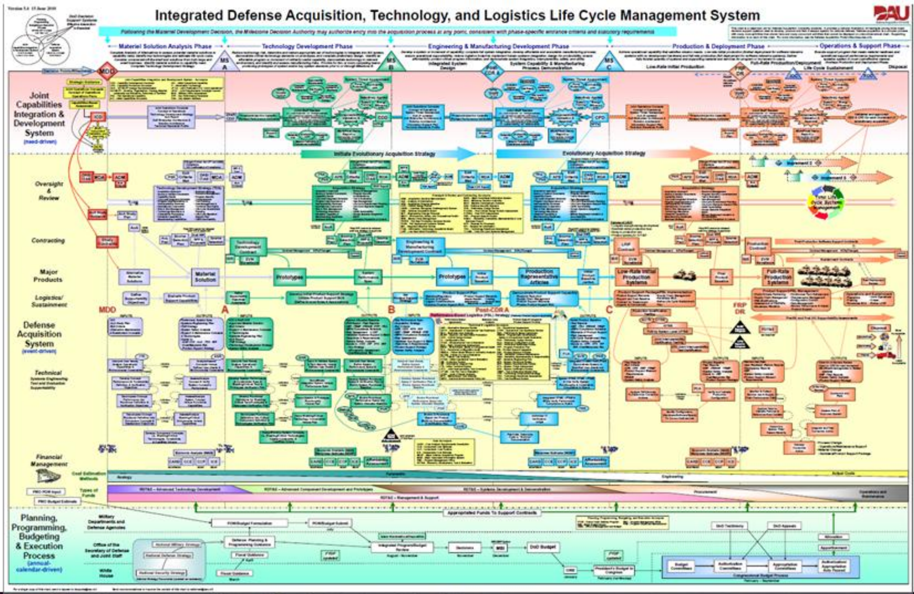
Systems Engineering, Acquisition, and Process



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UPDM Group

Systems Engineering, Acquisition, and Process

- National acquisition processes have evolved over time
  - Unique to each country and established by law
  - Fiendishly complex
  - Not necessarily fit for purpose
  - Resistant to change
- Adoption of a common process across countries is neither likely nor practical
  - Need to concentrate on MBSE best practice
  - Architecture standards
  - Certified Architect Standards
  - System Lifecycle Standards (15288)
  - Competency Frameworks
  - Etc.
- Most important, a process should NOT tie itself directly to a specific tool or tool vendor.

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Vertical and Horizontal Complementary Emerging Standards

- CA-FEA: The Common Approach to Federal Enterprise Architectures
- UML: The Unified Modelling Language.
- SysML: The Systems Modelling Language
- SoaML: The Service Oriented Architecture language
- NIEM: UML Profile for NIEM - provides a common method for defining XML schema conforming to the NIEM Specifications
- IEPV: Information Exchange Policy Vocabulary – provides a method for defining the business rule for the aggregation, transformation, tagging and filtering data and information to a specified message format.
- SOPES IEDM: Codified set of business rules for the JC3IEDM (STANAG 5525) conforming to compliance point 1 of the IEPV
- Etc.

OMG OBJECT MANAGEMENT GROUP

Unclassified

Common Approach

National IT Architecture Movement in the United States across all Government Departments, Agencies, and Organizations

Federal, State, and Local

Industry

Academia (Colleges and Universities)

Unclassified 33

Unclassified

Common Approach

Increasing Shared Approaches To Information Technology Services

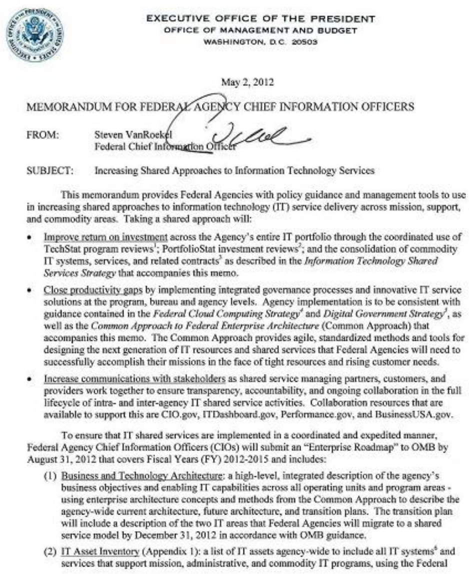
•Implements Governance Process

•Provides Authority to the Common Approach to a Unified Architecture Framework

•Provides Standards Methods and Tools

•Design and Implement Shared Services

•Design architectures that facilitates interoperability and information-sharing



EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

May 2, 2012

MEMORANDUM FOR FEDERAL AGENCY CHIEF INFORMATION OFFICERS

FROM: Steven VanRoekel
Federal Chief Information Officer

SUBJECT: Increasing Shared Approaches to Information Technology Services

This memorandum provides Federal Agencies with policy guidance and management tools to use in increasing shared approaches to information technology (IT) service delivery across mission, support, and commodity areas. Taking a shared approach will:

- Improve return on investment across the Agency's entire IT portfolio through the coordinated use of TechStat program reviews[1]; PortfolioStat investment reviews[2]; and the consolidation of commodity IT systems, services, and related contracts[3] as described in the *Information Technology Shared Services Strategy* that accompanies this memo.
- Close productivity gaps by implementing integrated governance processes and innovative IT service solutions at the program, bureau and agency levels. Agency implementation is to be consistent with guidance contained in the *Federal Cloud Computing Strategy*[4] and *Digital Government Strategy*[5], as well as the *Common Approach to Federal Enterprise Architecture* (Common Approach) that accompanies this memo. The Common Approach provides agile, standardized methods and tools for designing the next generation of IT resources and shared services that Federal Agencies will need to successfully accomplish their missions in the face of tight resources and rising customer needs.
- Increase communications with stakeholders as shared service managing partners, customers, and providers work together to ensure transparency, accountability, and ongoing collaboration in the full lifecycle of intra- and inter-agency IT shared service activities. Collaboration resources that are available to support this are CIO.gov, ITDashboard.gov, Performance.gov, and BusinessUSA.gov.

To ensure that IT shared services are implemented in a coordinated and expedited manner, Federal Agency Chief Information Officers (CIOs) will submit an "Enterprise Roadmap" to OMB by August 31, 2012 that covers Fiscal Years (FY) 2012-2015 and includes:

(1) Business and Technology Architecture: a high-level, integrated description of the agency's business objectives and enabling IT capabilities across all operating units and program areas - using enterprise architecture concepts and methods from the Common Approach to describe the agency-wide current architecture, future architecture, and transition plans. The transition plan will include a description of the two IT areas that Federal Agencies will migrate to a shared service model by December 31, 2012 in accordance with OMB guidance.

(2) IT Asset Inventory (Appendix 1): a list of IT assets agency-wide to include all IT systems[6] and services that support mission, administrative, and commodity IT programs, using the Federal

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Future Problems

- Systems of systems will grow in complexity and scale
  - Architectures will be necessary for understanding and governance
  - Essential for proper management and control
  - Tools will need to evolve to support this
- Individual national support of proprietary architecture frameworks will become unsupportable
  - Unaffordable
  - Not interoperable
  - A barrier to communications
- The ROI case for MBSE has not yet been made
  - Some evidence exists, but it is not yet overwhelming
  - PowerPoint Engineering is still the status quo

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A Call to Arms

- Development of the UAF will solve many problems (but not all)
  - Requires immediate support and funding from national governments
  - A change from "individual cars" to shared transport
  - Local variants will be necessary
- An interchange standard will be essential
  - Problems with PES or its replacement must be overcome
  - Work on interchange using RDF is looking promising
- Reference Architectures need to be created and shared
  - At both the capability and component level
- A fundamental change in process needs to happen
  - MBSE needs to change from "extra work" to "how things are done"
  - Tools need to evolve to better enable this change in process
- The case for MBSE ***Must*** be made
  - Industry partners ***Must*** publish more success stories
  - Governments ***Must*** require MBSE starting with the concept phase, the bid process and throughout the acquisition lifecycle

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Contact Details

Matthew.Hause@Atego.com

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12. A Proposed Pattern of Enterprise Architecture

Dr Clive Boughton
Australian National University

Abstract

The latest versions of the Department of Defence and Ministry of Defence Architecture Frameworks (DoDAF and MoDAF), as well as the Object Management Group's Unified Profile for DoDAF and MoDAF each employ a meta-model, thus providing a basis for effective implementation of tools for constructing consistent architecture descriptions.

UPDM comprises extensions to both OMG's Unified Modelling Language (UML) and Systems Modelling Language (SysML), and thus provides for architectural descriptions that contain a rich set of (formally) connected DoDAF/MoDAF viewpoints expressed in a form familiar to those who use UML and SysML.

These represent significant advancements that enable architecture trade-off analyses, architecture model execution, requirements traceability, and speedier transition to systems design and implementation. All very useful to both the enterprise architect and the solutions architect. But is there more that can be done, especially for those who should contribute input to the enterprise architecture?

In this paper an extra model/view in the form of a pattern is described that is intended to aid in the development of enterprise architectures (EA), both small and large. The proposed pattern of EA is developed using information extracted from the Computer Emergency Response Team Resilience Maturity Model (CERT RMM) and the Capability Maturity Model Integrated (CMMI) for Acquisition, and for Services as well as the People Maturity Model.

Although not completed, the pattern of EA is developed to the extent that some benefits from its use/application across several types of organisation are readily apparent. One of its main benefits is to allow business analysts/engineers early capture of EA requirements. A further benefit is that the 'pattern' should be easier for executive decision makers to appreciate and understand – without feeling technically incompetent.

Presenter Biography

As a professional, **Dr Clive Boughton** possesses over thirty years of practical experience in varying roles as scientist, engineer, software engineer, consultant, and project and company manager. His collective experiences have given him the opportunity to observe/research/manage and participate in commercial, defence and scientific software projects including native and embedded applications using contemporary techniques, languages and management methods.

Clive held a full time academic position at ANU from 2000 – 2010 during which time he developed the final touches to the (then) new Bachelor of Software Engineering. He also fully developed the Masters in Software Engineering, the major parts of which still exist in the MCOMP program. Clive is an adjunct associate professor at both the ANU and UQ.

He now spends most of his time undertaking all sorts of systems/software engineering consulting and project management work through Software Improvements, a company he set up in 1992.

Qualifications:

- BSc (Applied Physics) - RMIT - 1976,
- PhD (The Total Differential Scattering Cross Sections of some Weakly Anisotropic Molecules) – ANU – 1988.

Affiliations:

- Member ACM, Member IEEE Computer Society, Member ACS
- Chair of Australian Safety Critical Systems Association (aSCSa)

Main Research and Industry Interests

- Requirements Engineering
- Project Management
- Modelling Languages and Techniques
- Model-driven Development
- Software/Enterprise Architecture
- Software Measurement

Present Appointment

Technical Director and Chair of Board at Software Improvements Pty Ltd

Presentation

Context

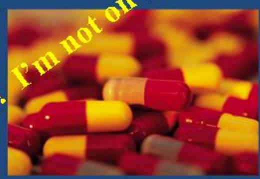
NOTHING HERE IS NEW!

No bombshells

Just throwing in some ideas & concepts!

Maybe some light bulb moments for you?

No! I'm not on drugs!



Not quite finished yet!

Proposed Pattern of EA Clive Boughton 2

What prompted my thinking?

Severally: Architecture, Processes, Decisions

- Interesting experiences and/or observations
  - Especially decisions and processes lacking 'logic'
- Seeing people reel from too much (mindless) change
  - As well as information overflow
- Seeing repercussions of many COTS 'solutions'
  - A COTS gives us 80% of the solution!! A silver bullet?!
  - Little / no analysis of options – a 'shaped' OCD
- Continuing, awkward integrations of business & IT
  - Even though 'architecture' has been around for a while
  - Despite the recognised imperative of up-to-date information
- Perhaps because I am confused
  - After all everything is getting more complex – isn't it?
  - Cost, time and quality still matter – don't they?

Proposed Pattern of EA Clive Boughton 3

Software Improvements

What prompted my thinking?

Stuff that's not being referred to or used often

- Architecture Frameworks – in last 5 years
  - DoDAF, MoDAF, latest versions are more holistic wrt EA
  - UPDM becoming very mature and supports MBSE well!
  - TOGAF seems to have significant following - doesn't seem to support MBSE.
- CMMI in last 10 years (from SEI & CERT)
  - Development
    - Covers systems & software – roots from SW-CMM 1991
  - Services
    - Greater than 80% of world economy
    - Greater than 50% US DoD acquisitions.
  - Acquisition
    - Most enterprises do this – began 1994
  - Resilience
    - Extends Services to include greater emphasis on business survival
  - People
    - For developing individual capability to shaping the workforce

Proposed Pattern of EA — Clive Boughton — 4

Software Improvements

Observations - 1

'Business' Organisations

- Most deemed to be *governed* by 'business strategy'
  - Strategic directions – driven by 'environment' (*change*).
  - Business needs – driven by 'market' (*change*).
  - Operational needs – driven by 'technology' (*change*).
  - Efficiency needs – driven by 'economy' (*change*).
- Most interventions cause significant and costly disruption
  - Few interventions are successful – particularly large ones
    - Don't live up to expectations or 'improve things'
    - Risk! What's that? We'll be right mate!
    - Take years to facilitate and get into shape
    - Leave a big '?' regarding value for money
    - Leave mostly LOSERS

Proposed Pattern of EA — Clive Boughton — 5

Observations - 2

'Business' Organisation Architectures

- Enterprise Architecture:
  - Mostly immature – or do not really exist
  - Typically 'controlled' by IT infrastructure
  - Infected with legacy constraints
  - Minimally documented – if they do exist
  - Rarely articulated as being associated with 'business'
  - .....
- Systems Architecture:
  - Usually seen as only the IT stuff
  - Sometimes seen as the EA (*because of multiple SAs*)
  - Sometimes appears completely separate to EA
  - .....

Proposed Pattern of EA   Clive Boughton   6

Observations - 3

'Business' Organisation Maturity Essentials

- Business
  - Structure
  - Nature
  - Stability
- Management
  - Style
- Capability
  - Consistency
  - Professional depth
- Resiliency
  - 'Ready' for impacts of change
  - Survivability

Proposed Pattern of EA   Clive Boughton   7

Overview of inputs

Organisations and their business

- Do they know what they do?
- Do they know their business drivers (and changers)?
- Are they struggling with the IT behemoth?

Enterprise architecture

- Is it all determined from OV-1?
- Is it overborne by IT constraints?
- A holistic view or a bitsy view (system-by-system)?

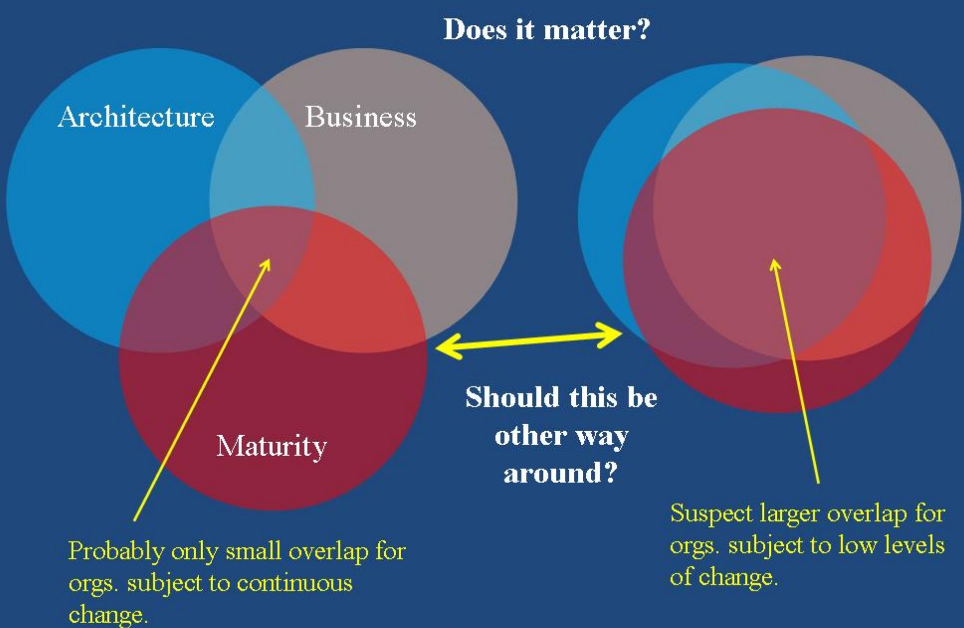
Architectural frameworks

- DoDAF emphasis now on data-centric process!
- DoDAF in context with FEA and OMB's EAAF!

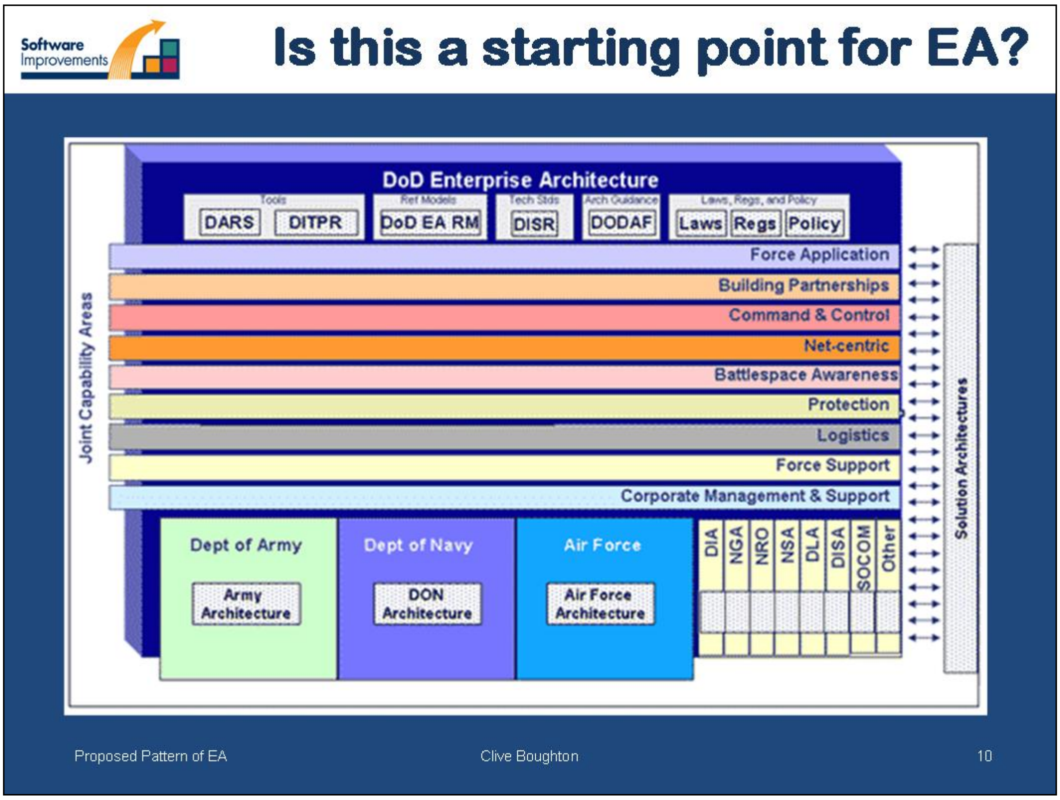
FEA = Federal EA, OMB = Office of Management & Budget, EAAF = EA Assessment Framework

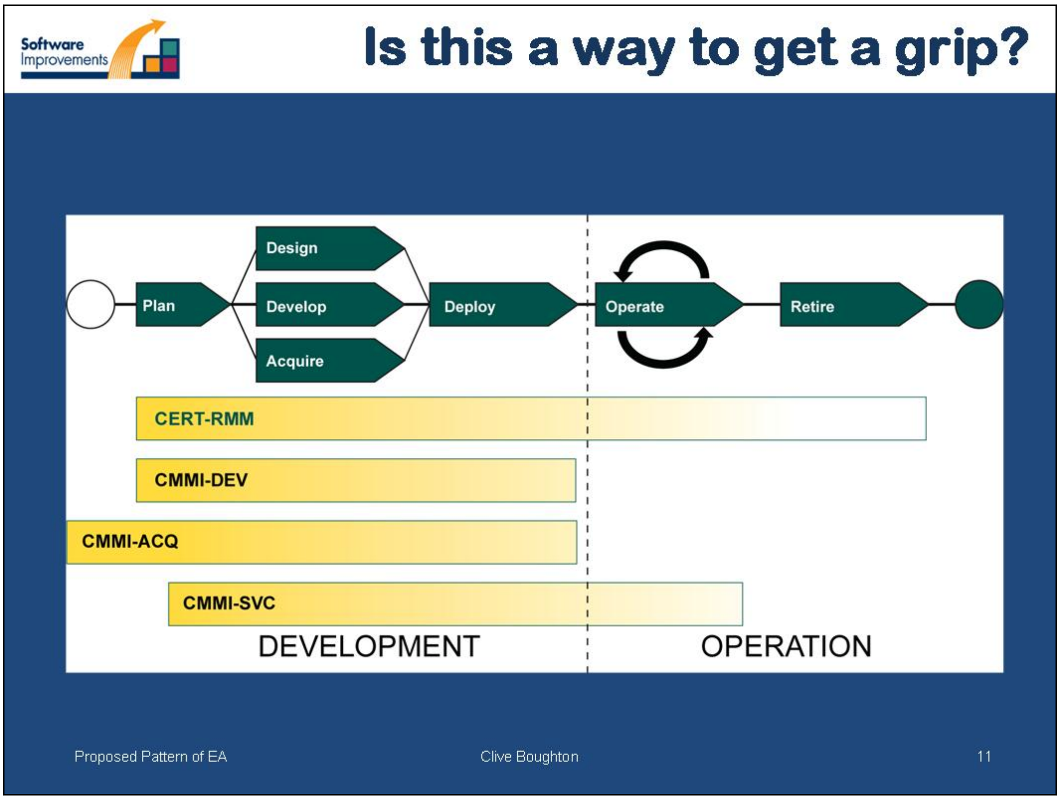
Proposed Pattern of EA Clive Boughton 8

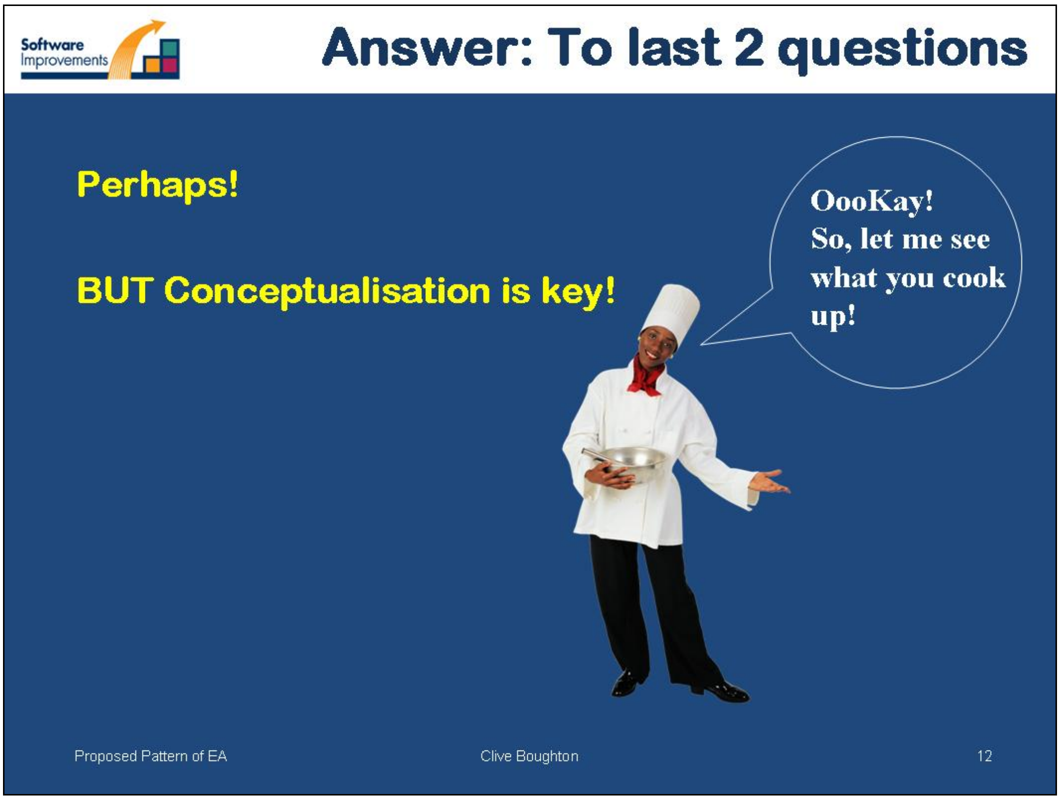
Optimal B-A-M overlap?

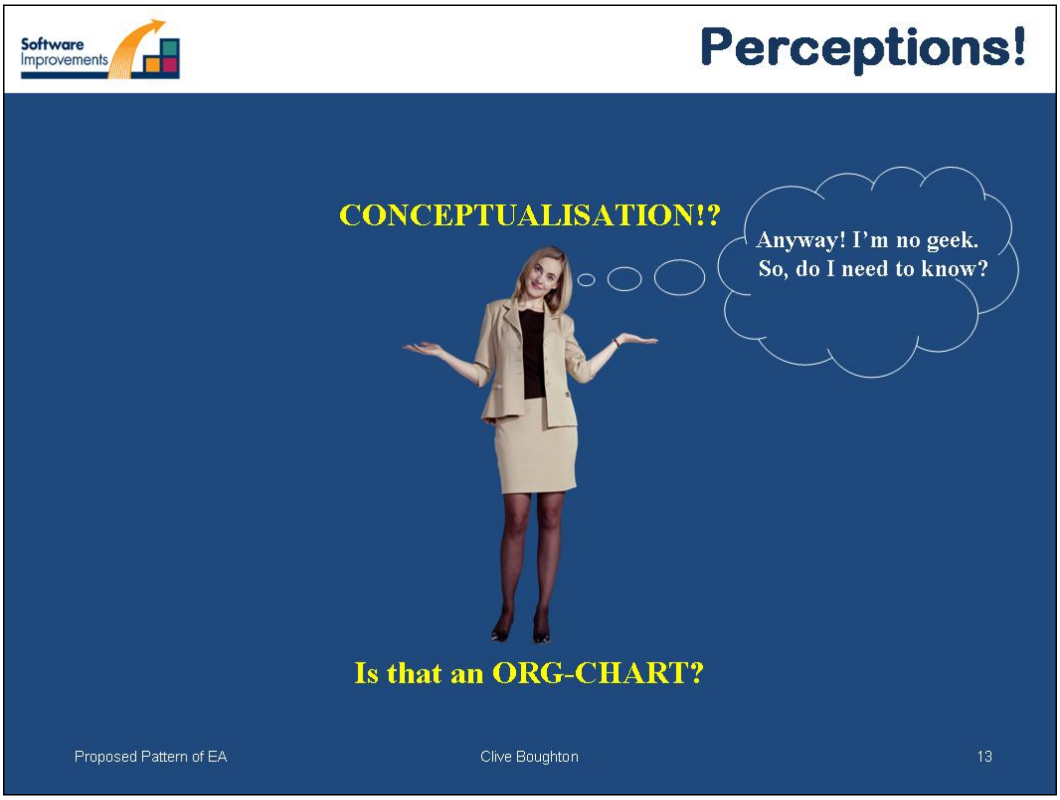


Proposed Pattern of EA Clive Boughton 9


Software Improvements
Is this a starting point for EA?
DoD Enterprise Architecture
Tools
DARS
DITPR
Ref Models
DoD EA RM
Tech Stds
DISR
Arch Guidance
DODAF
Laws, Regs, and Policy
Laws
Regs
Policy
Joint Capability Areas
Force Application
Building Partnerships
Command & Control
Net-centric
Battlespace Awareness
Protection
Logistics
Force Support
Corporate Management & Support
Dept of Army
Army Architecture
Dept of Navy
DON Architecture
Air Force
Air Force Architecture
DIA
NGA
NRO
NSA
DLA
DISA
SOCOM
Other
Solution Architectures
Proposed Pattern of EA
Clive Boughton
10


Software Improvements
Is this a way to get a grip?
Plan
Design
Develop
Acquire
Deploy
Operate
Retire
CERT-RMM
CMMI-DEV
CMMI-ACQ
CMMI-SVC
DEVELOPMENT
OPERATION
Proposed Pattern of EA
Clive Boughton
11


Software Improvements
Answer: To last 2 questions
Perhaps!
BUT Conceptualisation is key!
OooKay!
So, let me see
what you cook
up!
Proposed Pattern of EA
Clive Boughton
12


Software Improvements
Perceptions!
CONCEPTUALISATION!?
Anyway! I'm no geek.
So, do I need to know?
Is that an ORG-CHART?
Proposed Pattern of EA
Clive Boughton
13

Software Improvements

Properties

If thinking about systems and their conceptualisation it's appropriate to study some basic properties!

DATA	PROCESS	STATE
PROCESS	STATE	DATA
STATE	DATA	PROCESS

Treat a business organisation as a complex real-time system

Proposed Pattern of EA　　Clive Boughton　　14

Software Improvements

Clues: CERT-RMM & CMMI-Svc

Services

- Form a layer, decoupling Operational activities from organizational arrangements of resources, such as people and information systems.
- Form a pool that can be orchestrated in support of operational activities, and the Operational activities define the level of quality at which the Services are offered.

Capabilities

- Relate to Services via the realization of the Capability by a Performer that is a Service.
- In general, a Service would not provide the Desired Effect(s), but rather, [provide] access to ways and means (*activities & resources*) that would.

Proposed Pattern of EA　　Clive Boughton　　15

Software Improvements

Clues: CERT-RMM & CMMI-Svc

Operations

- Realise Capabilities.

Systems

- Help fulfill Capability requirements.
- Support Operational activities & facilitate information exchange.

Proposed Pattern of EA | Clive Boughton | 16

Software Improvements

Clues: CERT-RMM Proc. Areas

Engineering	Enterprise Management	Operations	Process Management
ADM	COMM	AM	MA
CTRL	COMP	EC	MON
RRD	EF	EXD	OPD
RRM	FRM	ID	OPF
RTSE	HRM	IMC	
SC	OTA	KIM	
	RISK	PM	
		TM	
		VAR	

Lots of processes but NO DATA MODEL!

Proposed Pattern of EA | Clive Boughton | 17

Software Improvements

Clues: Conceptual Data Model

DIV-1 (new in DoDAF 2.0):

- Addresses the information concepts at a high-level on an *operational architecture.*
- Used to document the business information requirements and structural business process rules of the *architecture.*
- Describes information that is associated with the information of the *architecture.* Includes information items, their attributes, and their inter-relationships.

The intended usage of the DIV-1 includes:

- Information requirements
- Information hierarchy

Proposed Pattern of EA Clive Boughton 18

Software Improvements

Clues: Logical Data Model

DIV-2:

- Allows analysis of an *architecture's* data definition aspect, independent of implementation / product specific issues.
- Provides a common data definition dictionary to consistently express model descriptions including -
  - Information in an OV-1 High Level Operational Concept Model or an Activity Resource flow object in an OV-5b Operational Activity Model.
  - Entities & elements constrained and validated by capture of business requirements in an OV-6a Operational Rules Model.
  - Information content of messages that connect life-lines in an OV-6c Event-Trace Description.
  - Elements required due to Standards in the StdV-1 Standards Profile or StdV-2 Standards Forecast.

Proposed Pattern of EA Clive Boughton 19

Clues: Logical Data Model

DIV-2:

- Bridges the gap between the conceptual data model and physical-levels.
- Introduces attributes and structural rules that form the data structure.
- Provides more detail than the conceptual data model.
- Communicates more to the architects and systems analysts types of stakeholders.

Proposed Pattern of EA   Clive Boughton   20

DoDAF Meta-Model Definitions

Activity: Work, not specific to a single organization, weapon system or individual that transforms inputs (Resources) into outputs (Resources) or changes their state.

Resource: Data, Information, Performers, Materiel, or Personnel Types that are produced or consumed.

- **Materiel:** Equipment, apparatus or supplies that are of interest, without distinction as to its application for administrative or combat purposes.
- **Information:** The state of a something of interest that is materialized - *in any medium or form* - and communicated or received.
  - **Data:** *Representation of information in a formalized manner suitable for communication, interpretation, or processing by humans or by automatic means. Examples could be whole models, packages, entities, attributes, classes, domain values, enumeration values, records, tables, rows, columns, and fields.*
  - **Architectural Description:** *Information describing an architecture such as an OV-5b Operational Activity Model.*

Proposed Pattern of EA   Clive Boughton   21

DoDAF Meta-Model Definitions

- **Performer**: Any entity - *human, automated, or any aggregation of human and/or automated* - that performs an activity and provides a capability.
  - **Organization:** *A specific real-world assemblage of people and other resources organized for an on-going purpose.*
  - **System:** *A functionally, physically, and/or behaviorally related group of regularly interacting or interdependent elements.*
  - **Person Type:** *A category of persons defined by the role or roles they share that are relevant to an architecture.*
  - **Service:** *A mechanism to enable access to a set of one or more capabilities, where the access is provided using a prescribed interface and is exercised consistent with constraints and policies as specified by the service description. The mechanism is a Performer. The capabilities accessed are Resources - Information, Data, Materiel, Performers, and Geo-political Extents.*

Proposed Pattern of EA   Clive Boughton   22

DoDAF Meta-Model Definitions

Capability: The ability to achieve a Desired Effect under specified (performance) standards and conditions through combinations of ways and means (activities and resources) to perform a set of activities.

Condition: The state of an environment or situation in which a Performer performs.

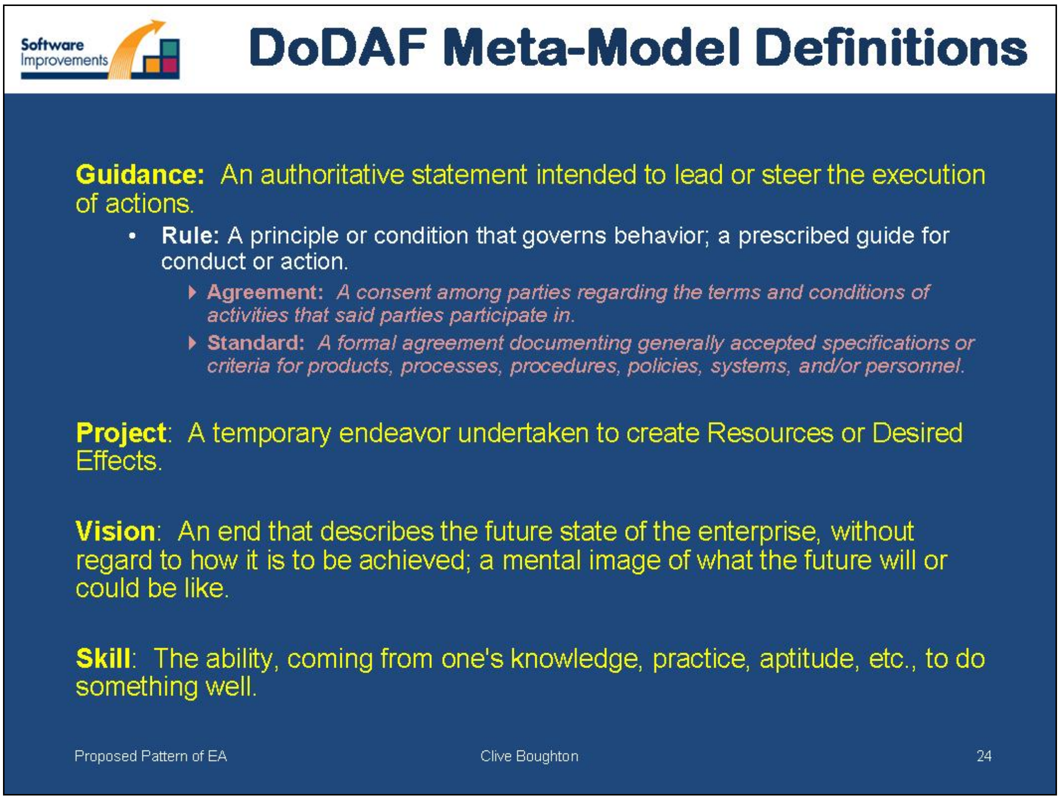
Desired Effect: A desired state of a Resource.

Measure: The magnitude of some attribute of an individual.

Measure Type: A category of Measures.

Location: A point or extent in space that may be referred to physically or logically.

Proposed Pattern of EA   Clive Boughton   23


Software Improvements
DoDAF Meta-Model Definitions
Guidance: An authoritative statement intended to lead or steer the execution of actions.
Rule: A principle or condition that governs behavior; a prescribed guide for conduct or action.
Agreement: A consent among parties regarding the terms and conditions of activities that said parties participate in.
Standard: A formal agreement documenting generally accepted specifications or criteria for products, processes, procedures, policies, systems, and/or personnel.
Project: A temporary endeavor undertaken to create Resources or Desired Effects.
Vision: An end that describes the future state of the enterprise, without regard to how it is to be achieved; a mental image of what the future will or could be like.
Skill: The ability, coming from one's knowledge, practice, aptitude, etc., to do something well.
Proposed Pattern of EA
Clive Boughton
24


Software Improvements
Basic Properties - 1
'Business' Organisations
Usually driven by desired goals & have a mission
Usually comprise:
Financial 'systems'
Human resource 'systems'
Assets (property, equipment, people)
Administrative 'systems'
Typically provide:
Services (and their maintenance)
Products (and their maintenance)
Sometimes undertake:
Acquisitions
Developments
Proposed Pattern of EA
Clive Boughton
25

Software Improvements

Basic Properties - 2

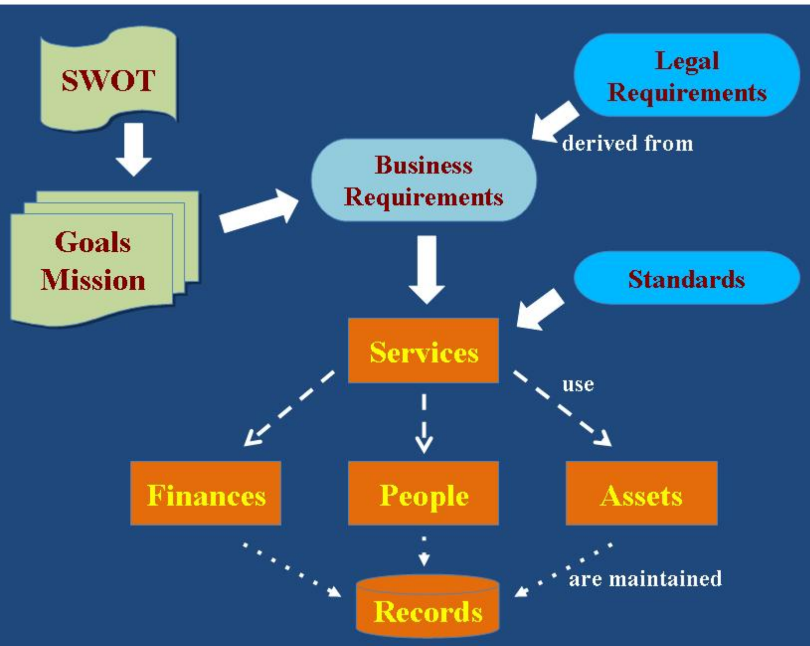
'Business' Organisations

- Typically see assets as:
  - Buildings
  - Vehicles
  - Furniture
  - Computing equipment
  - .....
- Often DON'T see assets as:
  - People
  - Information
    - client information maybe an exception
  - .....

Proposed Pattern of EA   Clive Boughton   26

Software Improvements

A Conceptual Model?



Proposed Pattern of EA   Clive Boughton   27

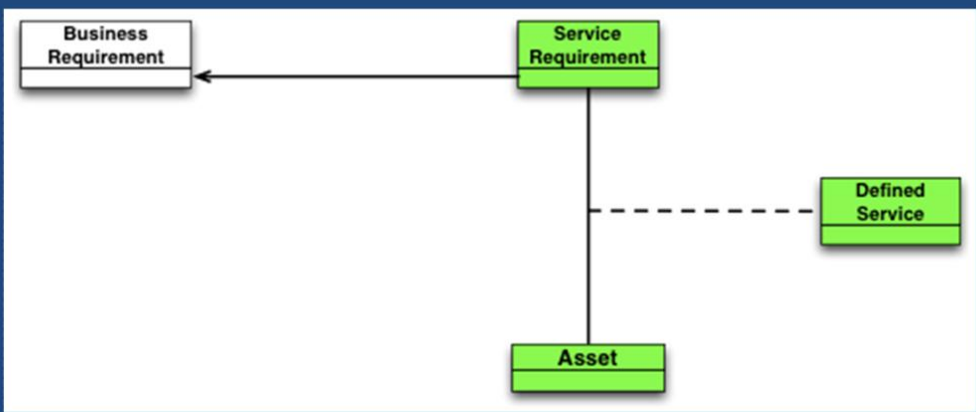
Potential issues

Lots can go wrong

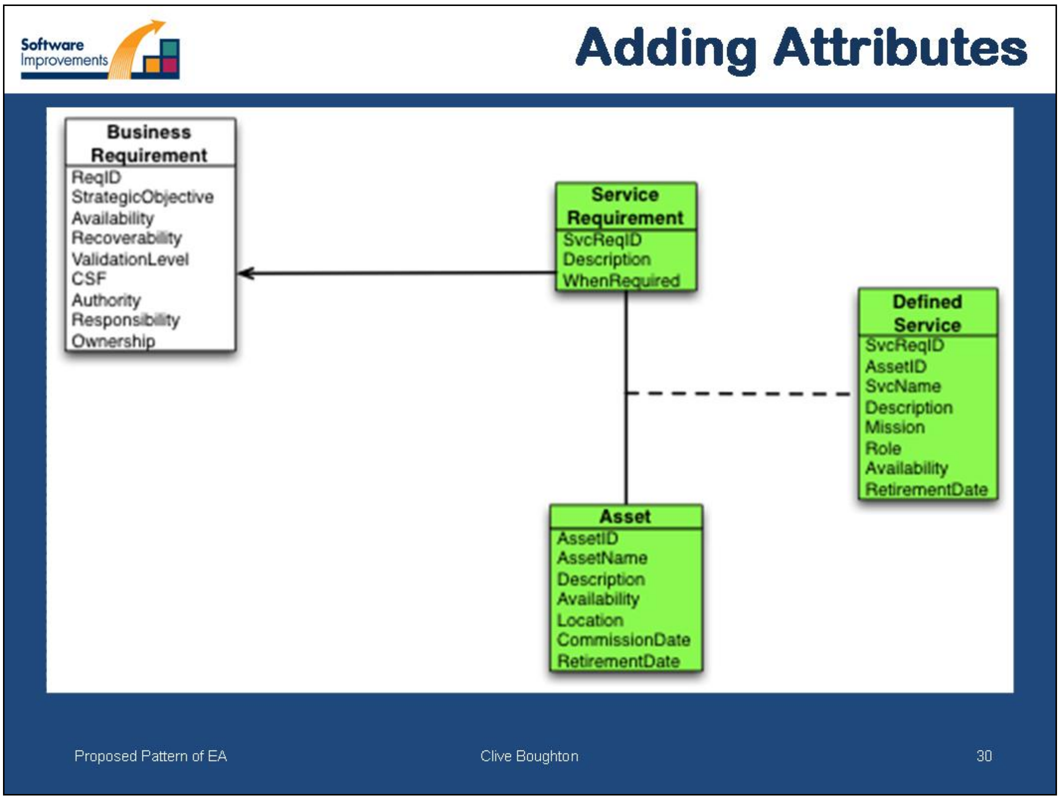
- SWOT
  - Too many Ws & Ts
- Forgot the mission
  - Didn't pass grandmother test (Don Watson – Weasel Words)
- New legal requirements
  - Requiring significant changes to services / products
- New standards
- Poor service delivery
- Bad financial management
- Ageing assets
- A workforce growing more 'inflexible'

Proposed Pattern of EA Clive Boughton 28

The Basic Concept Model



Proposed Pattern of EA Clive Boughton 29


Software Improvements
Adding Attributes
Business Requirement
ReqID
StrategicObjective
Availability
Recoverability
ValidationLevel
CSF
Authority
Responsibility
Ownership
Service Requirement
SvcReqID
Description
WhenRequired
Defined Service
SvcReqID
AssetID
SvcName
Description
Mission
Role
Availability
RetirementDate
Asset
AssetID
AssetName
Description
Availability
Location
CommissionDate
RetirementDate
Proposed Pattern of EA
Clive Boughton
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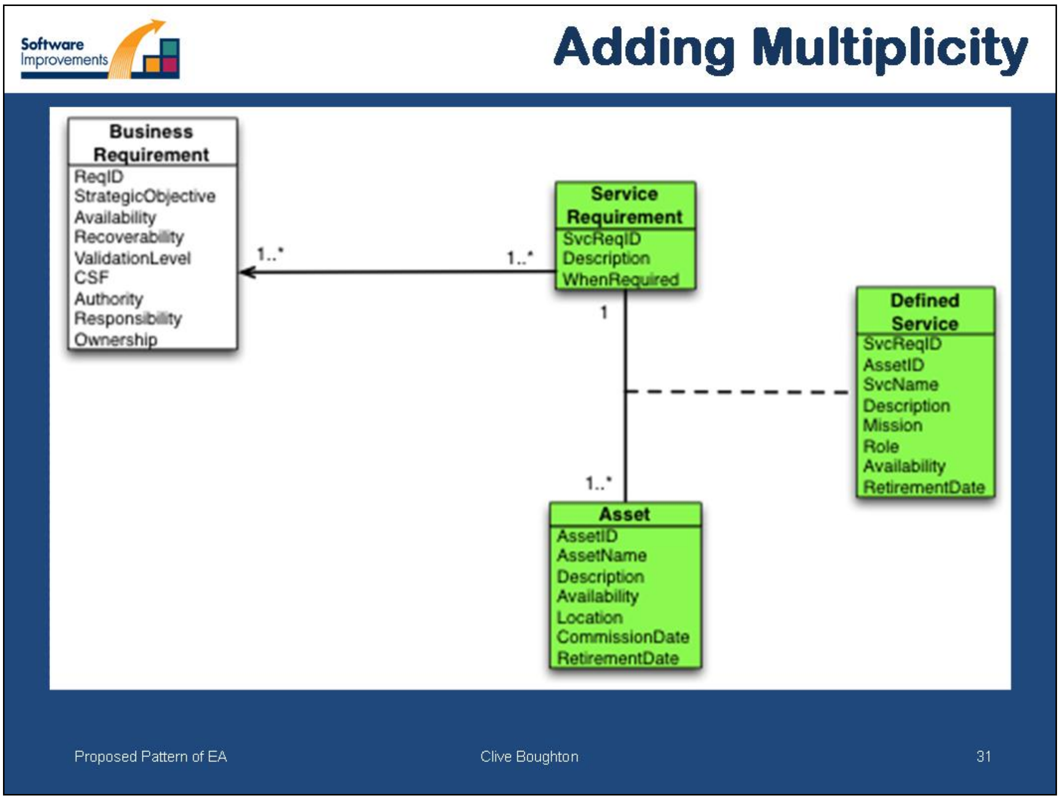
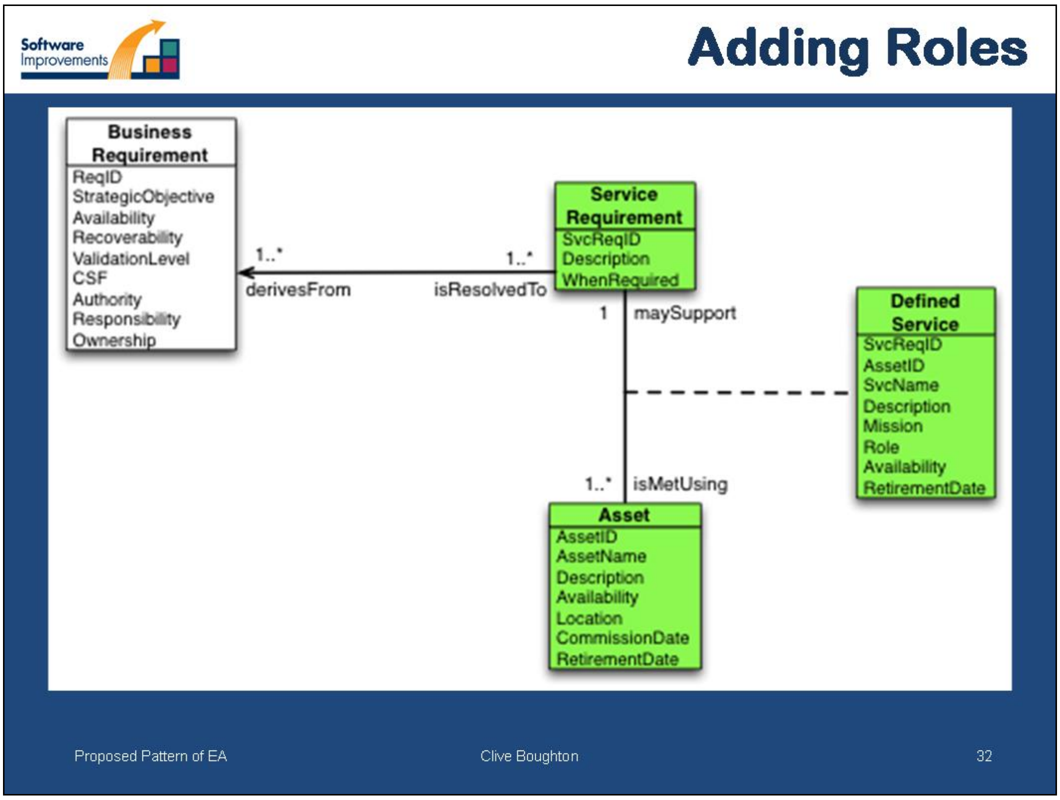

Software Improvements
Adding Multiplicity
Business Requirement
ReqID
StrategicObjective
Availability
Recoverability
ValidationLevel
CSF
Authority
Responsibility
Ownership
1..*
1..*
Service Requirement
SvcReqID
Description
WhenRequired
1
Defined Service
SvcReqID
AssetID
SvcName
Description
Mission
Role
Availability
RetirementDate
1..*
Asset
AssetID
AssetName
Description
Availability
Location
CommissionDate
RetirementDate
Proposed Pattern of EA
Clive Boughton
31


Software Improvements
Adding Roles
Business Requirement
ReqID
StrategicObjective
Availability
Recoverability
ValidationLevel
CSF
Authority
Responsibility
Ownership
1..*
derivesFrom
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isResolvedTo
Service Requirement
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Description
WhenRequired
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maySupport
Defined Service
SvcReqID
AssetID
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Role
Availability
RetirementDate
1..*
isMetUsing
Asset
AssetID
AssetName
Description
Availability
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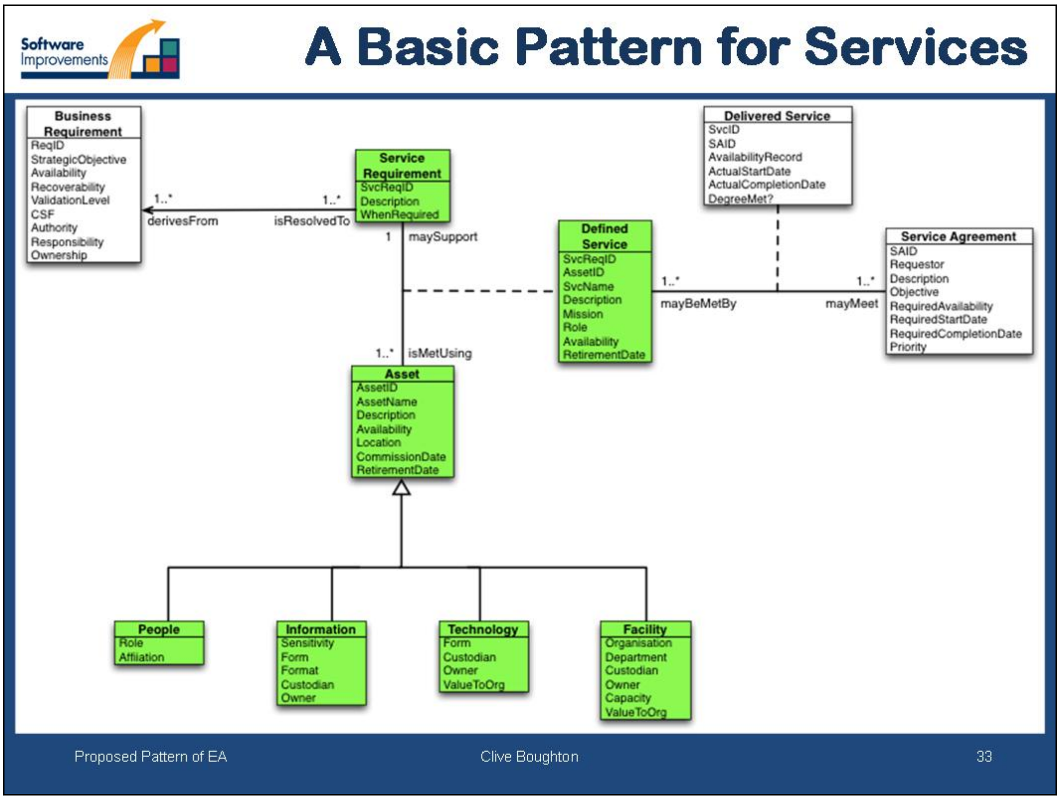
CommissionDate
RetirementDate
Proposed Pattern of EA
Clive Boughton
32


Software Improvements
A Basic Pattern for Services
Business Requirement
ReqID
StrategicObjective
Availability
Recoverability
ValidationLevel
CSF
Authority
Responsibility
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1..*
derivesFrom
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Service Agreement
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Requestor
Description
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Technology
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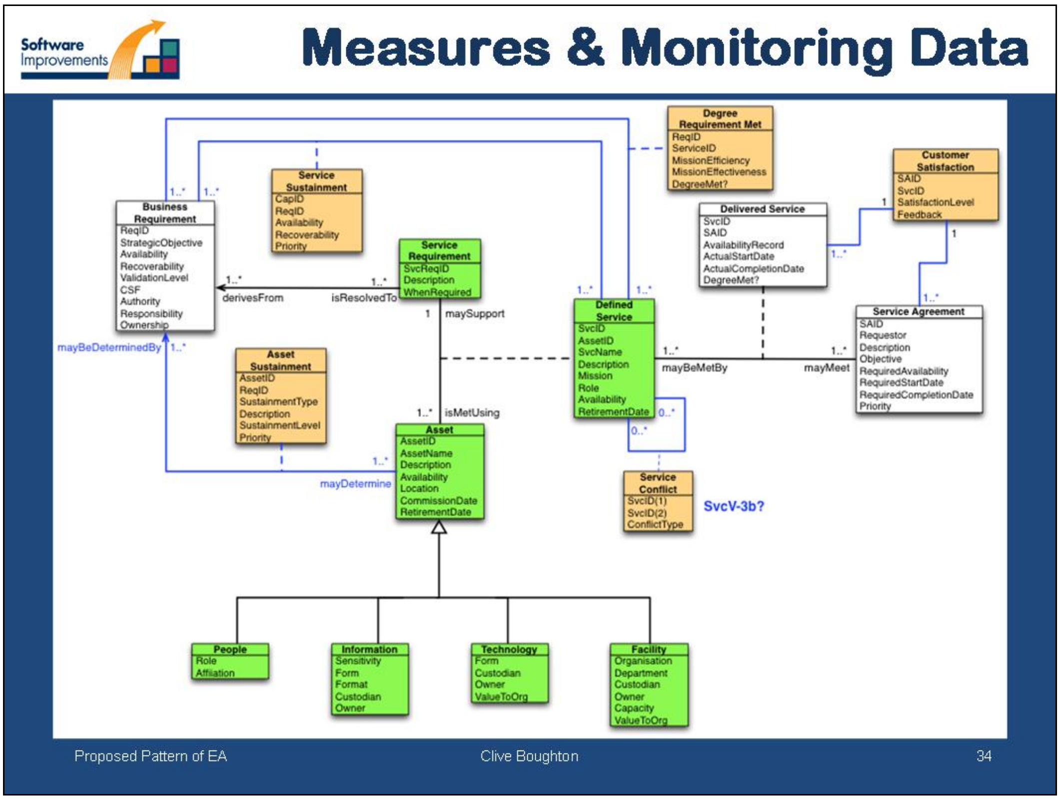
Proposed Pattern of EA
Clive Boughton
33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Measures & Monitoring Data
Degree Requirement Met
ReqID
ServiceID
MissionEfficiency
MissionEffectiveness
DegreeMet?
Service Sustainment
CapID
ReqID
Availability
Recoverability
Priority
Customer Satisfaction
SAID
SvcID
SatisfactionLevel
Feedback
Business Requirement
ReqID
StrategicObjective
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RetirementDate
Service Agreement
SAID
Requestor
Description
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RequiredAvailability
RequiredStartDate
RequiredCompletionDate
Priority
mayBeMetBy
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mayBeDeterminedBy
Asset Sustainment
AssetID
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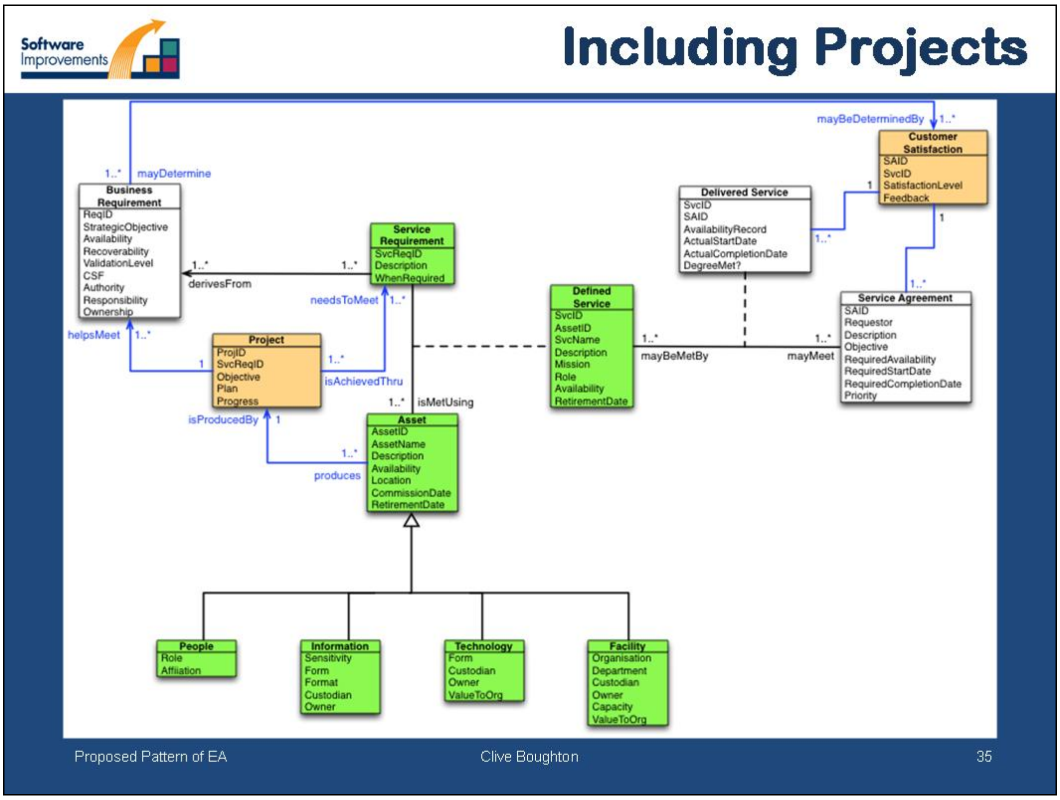
SustainmentType
Description
SustainmentLevel
Priority
isMetUsing
Asset
AssetID
AssetName
Description
Availability
Location
CommissionDate
RetirementDate
mayDetermine
Service Conflict
SvcID(1)
SvcID(2)
ConflictType
SvcV-3b?
People
Role
Affiliation
Information
Sensitivity
Form
Format
Custodian
Owner
Technology
Form
Custodian
Owner
ValueToOrg
Facility
Organisation
Department
Custodian
Owner
Capacity
ValueToOrg
Proposed Pattern of EA
Clive Boughton
34


Software Improvements
Including Projects
mayBeDeterminedBy
Customer Satisfaction
SAID
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SatisfactionLevel
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Business Requirement
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Recoverability
ValidationLevel
CSF
Authority
Responsibility
Ownership
Delivered Service
SvcID
SAID
AvailabilityRecord
ActualStartDate
ActualCompletionDate
DegreeMet?
Service Requirement
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WhenRequired
derivesFrom
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Defined Service
SvcID
AssetID
SvcName
Description
Mission
Role
Availability
RetirementDate
Service Agreement
SAID
Requestor
Description
Objective
RequiredAvailability
RequiredStartDate
RequiredCompletionDate
Priority
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Project
ProjID
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Objective
Plan
Progress
isAchievedThru
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mayMeet
isMetUsing
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Format
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Technology
Form
Custodian
Owner
ValueToOrg
Facility
Organisation
Department
Custodian
Owner
Capacity
ValueToOrg
Proposed Pattern of EA
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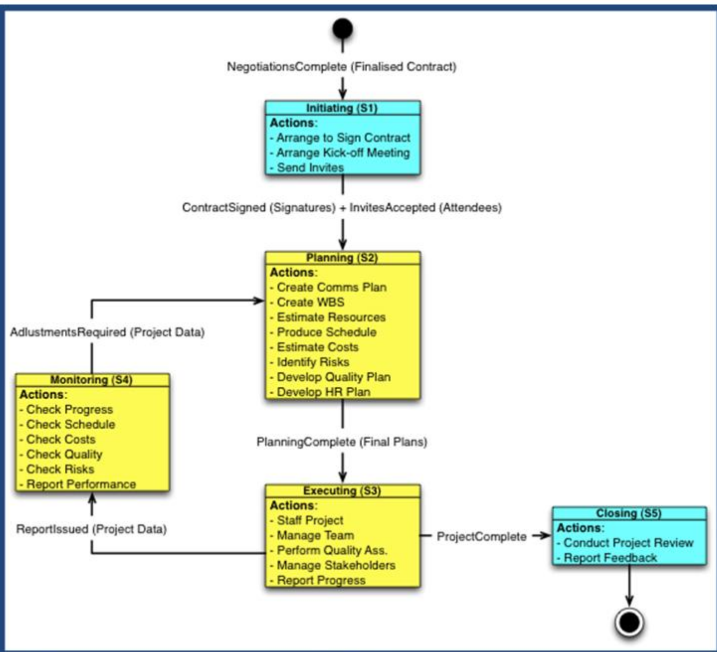
Software Improvements

Life Cycle States



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Software Improvements

An Essential Model

Advantages

- Provides the 'essential' fabric of an enterprise
  - Data PLUS data relationships - NOT just data!
  - Better still – NORMALISATION (for continuing integrity)
  - IMPLEMENTATION-FREE (requirements are the changer)
  - Traceability enables easy analysis of impacts of change(s)
  - Allows for 'optimum' implementation
  - Supports incremental development
- State model can be easily added
  - Introduces 'events' that drive or change the system
  - Further enables discovery of impacts of change before implementing any change
- Process models can be easily added
  - Includes actions to be taken when particular events occur
  - Defines 'expected' behaviour

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Software Improvements

Information Model

Advantages

- Can obtain a comprehensive (logical) model:
  - Of essential enterprise requirements – which can be used to build and / or evaluate any particular enterprise
  - Of architectural and design building blocks that are free from any (vendor) implementation
  - Based on other mature models concerning enterprises (e.g., CERT-RMM, CMMI-Svc)
  - That can be 'mapped' to existing enterprise when it's difficult to comprehend what to do when undertaking 'changes'
  - That enables more effective and more timely enterprise process improvement
  - Useful for simulation and automated development – NIRVANA (for some)!
- Strongly supports MBSE!!

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Software Improvements

Usefulness of Model

To Executives

- Only a few concepts and representations to learn and remember – and they can be kept simple!
- Not limited to OV-1 (*I think this is good!*)
- Aligns better with basic visualisations of what a business organisation does.
- Enables simplified views – for different levels of understanding
- Discussions can remain conceptual in nature – there's no technology but an executive has a greater opportunity to understand whether an implementation technology has been successful or not.

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Software Improvements

Usefulness of Model

To Architects

- Less translation is required before discussions with executives.
- Provides a common point of understanding.
- Traceability to requirements enables impacts of changes to be discovered and described more easily.
- Can use model to more quickly undertake architectural and design tradeoffs - AADL and more advanced modeling tools will be very useful here.
- Can use model to effect simulation – again AADL and the more advanced modeling tools may be very useful.

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Software Improvements

The Pattern

OoKay!
But you mentioned something about a pattern.

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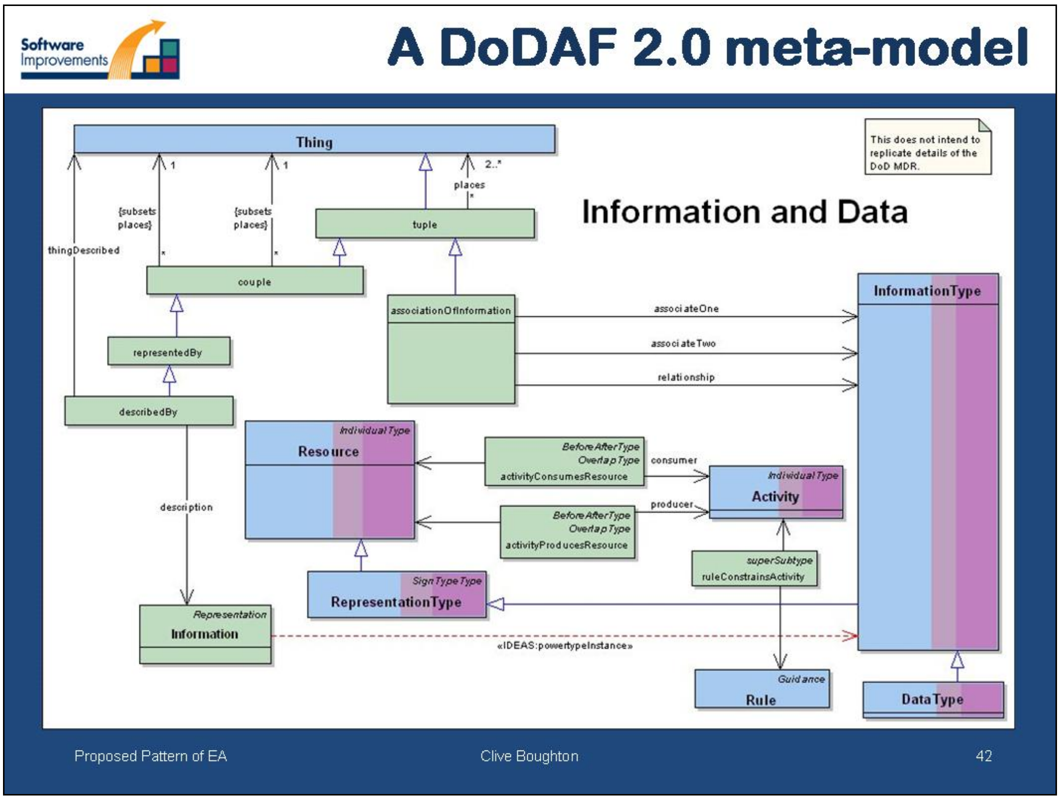
Software Improvements
A DoDAF 2.0 meta-model
Information and Data
This does not intend to replicate details of the DoD MDR.
Thing
tuple
places
{subsets places}
{subsets places}
thingDescribed
couple
associationOfInformation
associateOne
associateTwo
relationship
InformationType
representedBy
describedBy
Individual Type
Resource
BeforeAfterType
OverlapType
activityConsumesResource
consumer
Individual Type
Activity
producer
BeforeAfterType
OverlapType
activityProducesResource
description
superSubtype
ruleConstrainsActivity
SignTypeType
RepresentationType
Representation
Information
«IDEAS:powertypeInstance»
Guidance
Rule
DataType
Proposed Pattern of EA
Clive Boughton
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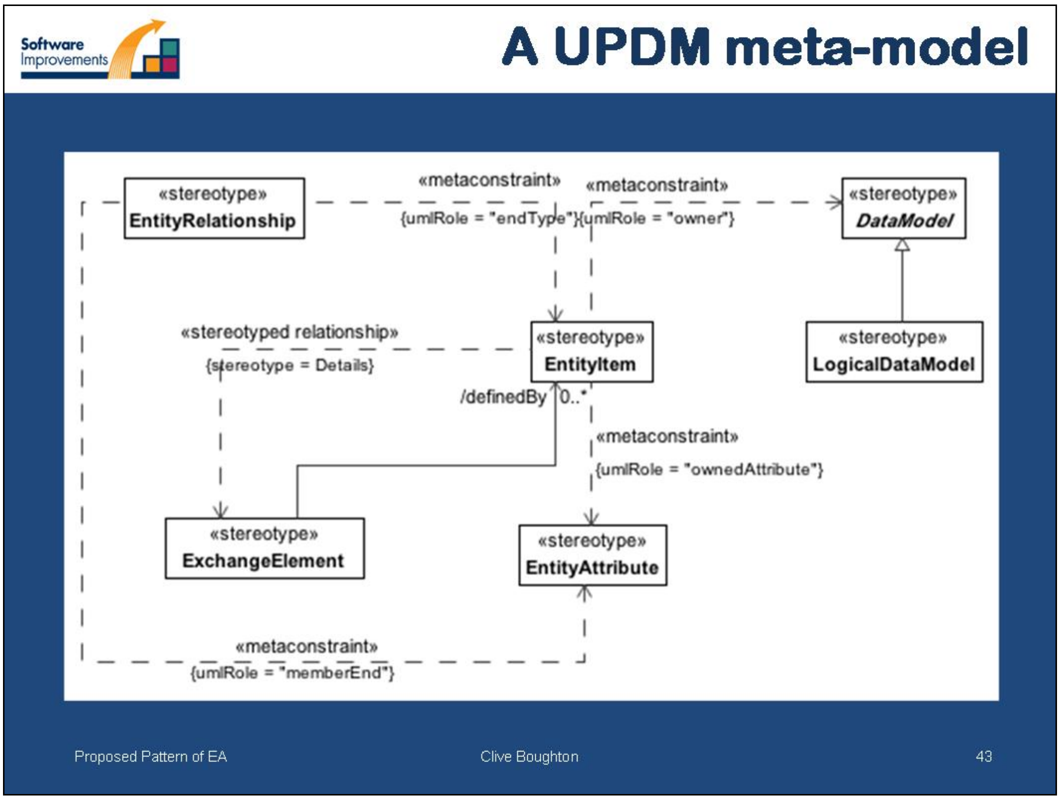
Software Improvements
A UPDM meta-model
«stereotype»
EntityRelationship
«metaconstraint»
{umlRole = "endType"}
«metaconstraint»
{umlRole = "owner"}
«stereotype»
DataModel
«stereotyped relationship»
{stereotype = Details}
«stereotype»
EntityItem
«stereotype»
LogicalDataModel
/definedBy
0..*
«metaconstraint»
{umlRole = "ownedAttribute"}
«stereotype»
ExchangeElement
«stereotype»
EntityAttribute
«metaconstraint»
{umlRole = "memberEnd"}
Proposed Pattern of EA
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5. CMMI for Acquisition v1.3 CMU/SEI-2010-TR-032
6. CMMI for Acquisition Primer v1.3 CMU/SEI-2010-TR-010
7. Understanding and Leveraging a Supplier's CMMI Efforts: A Guidebook for Acquirers CMU/SEI-2007-TR-004
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9. CERT Resilience Management Model v1.0 CMU/SEI-2010-TR-012
10. People CMM v2.0 CMU/SEI-2001-MM-01
11. Model-Based Engineering with AADL by P. Feiler and D. Gluch 2013
12. Measuring Operational resilience Using CERT-RMM CMU/SEI-2010-TN-030
13. Measures for Managing Operational Resilience CMU/SEI-2011-TR-019
14. Resilience Thinking: Sustaining Ecosystems & People in a Changing World by B. Walker and D. Salt 2006
15. Resilience Practice: Building Capacity to Absorb Disturbance & Maintain Function by B. Walker and D.Salt

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Questions

Now you're inviting trouble!

Are you sure this sign is small enough?

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13. Incorporating MBSE into SoS Engineering Practice

Pin Chen[1] and Mark Unewisse[2]
[1]Maritime Operations Division, DSTO and [2]Land Operations Division, DSTO

Abstract

The engineering of complex systems-of-systems (SoS) is one of the main challenges facing Defence in the development, acquisition and implementation of integrated warfighting capabilities. SoSs are ubiquitous within Defence, yet there is currently little effort to engineer these systems and capabilities.

This presentation explores the nature of SoS, SoS engineering (SoSE) and the potential for MBSE to support SoSE. It includes a discussion of:

1) an understanding of military SoS in terms of its variety, formation, evolution and complexity;
2) an understanding of SoS activities throughout lifecycles and in evolution;
3) potential roles of MBSE in and relation to SoSE practice; and
4) key challenges and opportunities for applications of MBSE for defence SoSE.

Some important issues and features of SoS are explored, including military SoS variety, different SoS perspectives, SoS processes and SoS complexity and well-being. SoSE engineering is discussed, addressing the difference from traditional systems engineering and the US DoD approach to SoSE. Incorporating MBSE into defence SoSE practice is shown to be a necessary, albeit challenging, step in developing practical approaches to SoSE. This will require improvements and extensions of MBSE concepts, processes and tools in order to adequately and successfully address SoS challenges and issues.

Presenter Biographies

Dr Pin Chen is a Senior Scientist in Maritime Operations Division, Defence Science & Technology Organisation (DSTO). Dr Chen's main research interests include Architecture Practice, Systems Engineering for SoS, complex systems design, and complexity management. Dr Chen joined DSTO 1996 after he completed his Ph.D. in Computer Science at the Australian National University. Previously, Dr Chen led research tasks and studies in several fields, including architecture practice study, architecture information model development for architecture repository, SoSSE, and Unmanned Underwater Vehicle (UUV) cooperation modelling and design.

Dr Mark Unewisse is a Principal Research Scientist with the Land Operations Division of the DSTO, leading the Land Capability Integration program. His 28 year career with Defence has spanned: submarine and surface ship simulation systems; infrared optoelectronic systems; Land force C2 systems; military experimentation; Army aviation; Land and Joint Fires; Combat Vehicle Systems; Land NCW; force-level integration; force protection; and supporting the RAAF Combat Support Group. In addition, Mark has undertaken a wide range of corporate and leadership roles within DSTO. Mark's current research efforts include: system-of-systems integration, tactical land Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) and the implementation of networked force capability.

Presentation

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Overview

What are SoSs?

SoS Engineering

Potential Role of MBSE in SoS Engineering

A Challenge for MBSE

Conclusion

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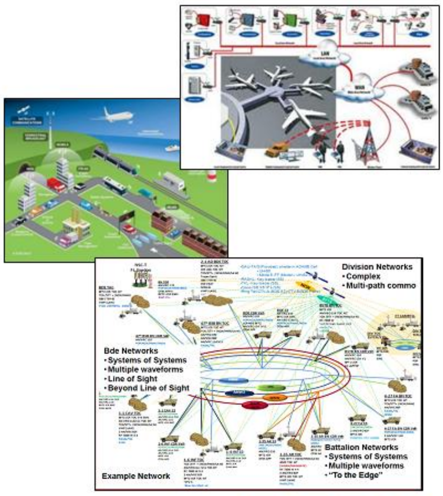
What are SoS?

Collection of heterogeneous systems that work together to deliver a larger scale emergent behaviour, characterised by:

- Operational Independence of Elements
- Managerial Independence of Elements
- Evolutionary Development
- Geographical Distribution of Elements
- Networks of Systems

SoS are all around us

- Civil
  - Airport
  - Transport Network
  - Mines
- Military
  - Primary focus of this presentation



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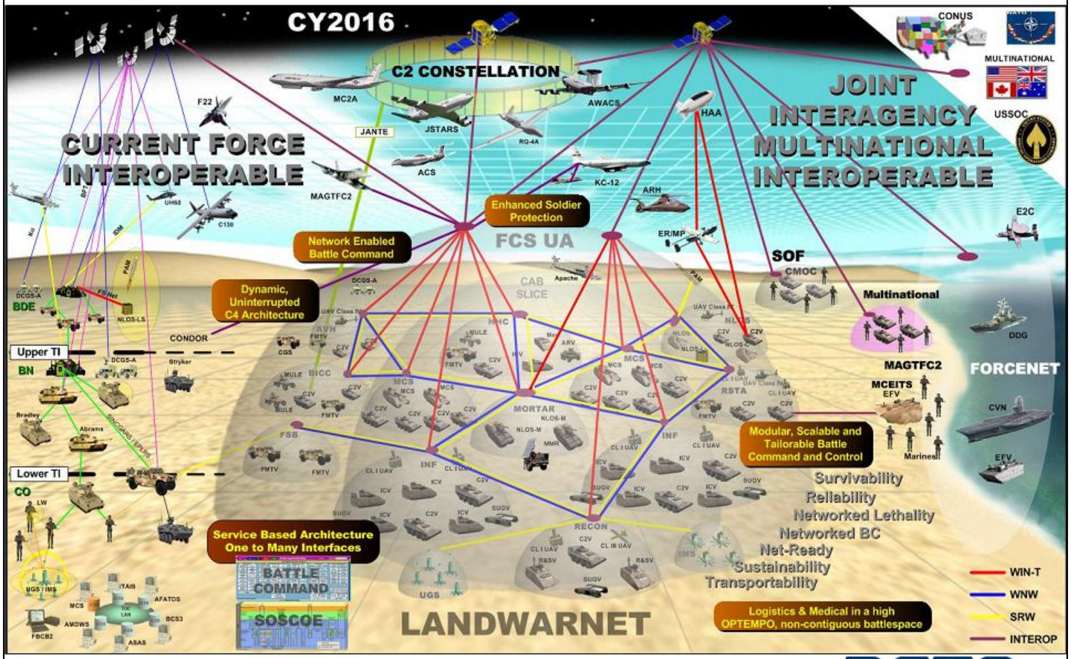
Examples of SoS in Defence



Source: Monica Farah-Stapleton, IEEE SoS Conference, 2006

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SoS Variety and 'Weltanschauung'

Wide variety of SoS varying with:

- Form, function, scale, diversity, rate of change …

Defence SoS can be view from multiple perspectives

- Platform Based
- System Based
- Capability Based
- Force Based
- Operational Based

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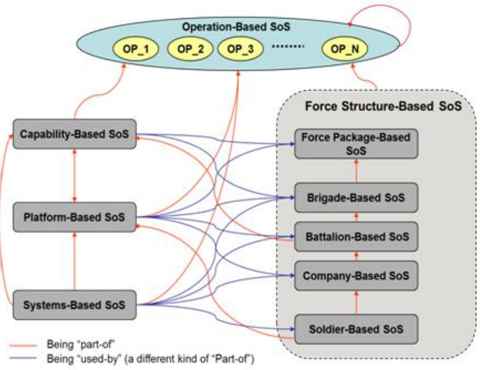
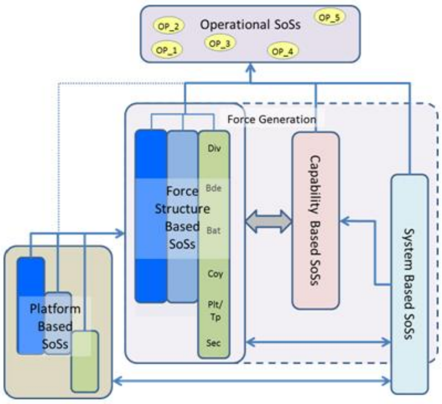
Interactions between SoS Perspectives

Interactions between the SoS perspectives
- Adding to overall SoS Complexity





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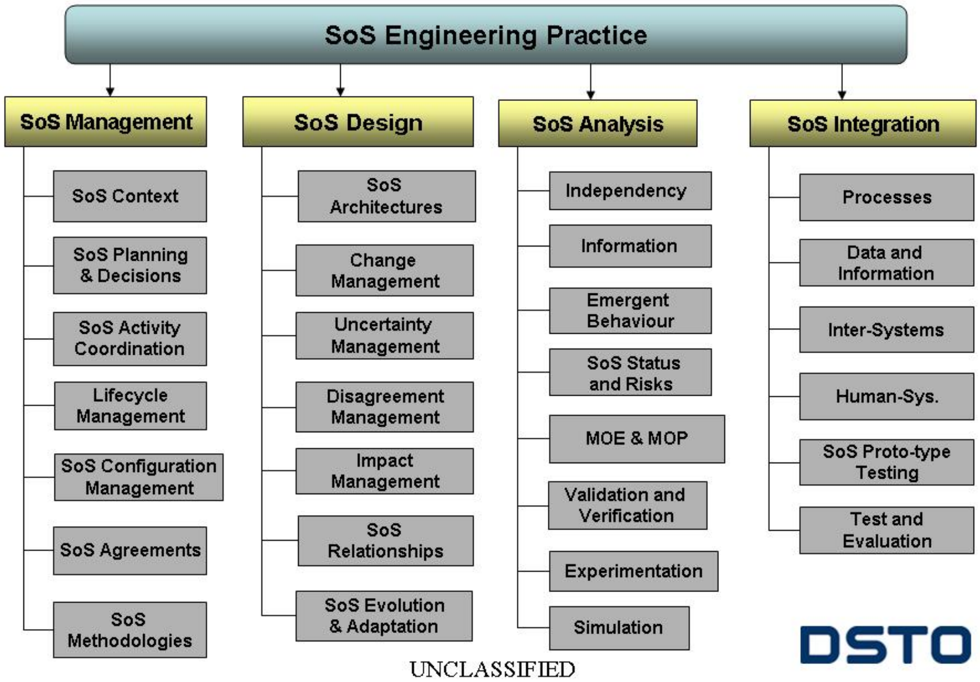
Defence SoS Activity Ontology (under development)



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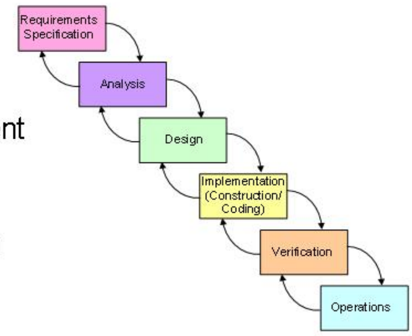
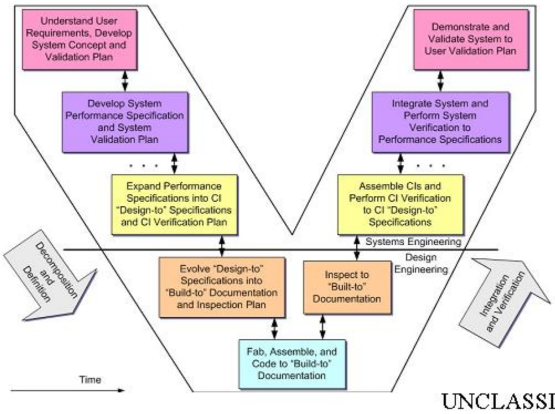
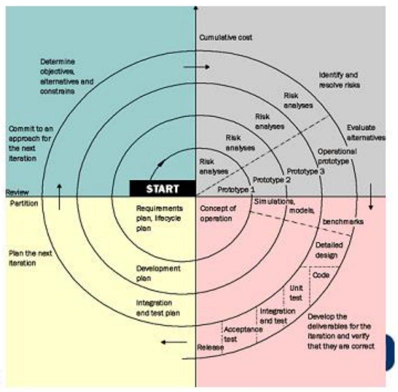
Traditional SE Process Models



Systems engineering process and management

- mainly for top down systems development
- theoretically for any system
- However, serious problems and difficulties in addressing the engineering of SoS





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SoSE is different from Traditional SE

SoSE is rarely top down – rather middle out

SoS can be either new or existing

- Often enduring capabilities
- Overlay an ensemble of existing, evolving, and new systems

SoS managers, when designated:

- Typically do not control all the requirements or funding of component systems
- can only influence

SoSE typically focuses on the evolution of capability over time

Levels of SoSE management maturity:

- Virtual
- Collaborative
- Acknowledged
- Directed

Most Australian Defence SoS are at this level

- Seeking to increase this to acknowledged

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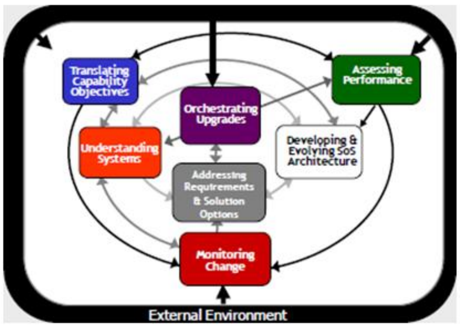
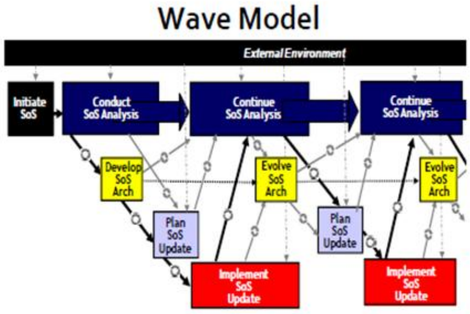
US DoD Approach to SoSE

US DoD has identified 7 Key elements of SoSE:

1. Translating SoS capability objectives into high-level SoS requirements
2. Understanding the constituent systems and their relationships
3. Assessing extent to which SoS performance meets capability objectives
4. Developing, evolving and maintaining an architecture for the SoS
5. Monitoring and assessing potential impacts of changes on SoS performance
6. Addressing SoS requirements and solution options
7. Orchestrating upgrades to SoS





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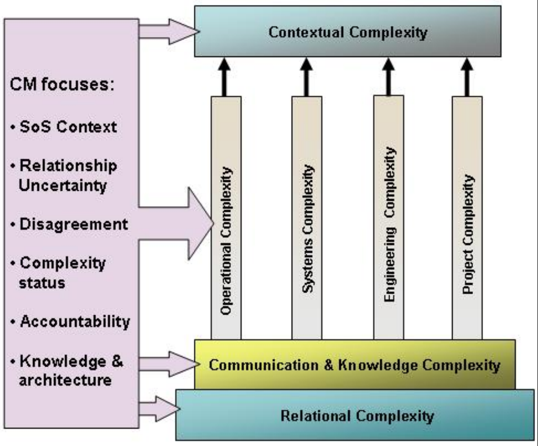
Managing SoS Complexity and Well Being

US DoD outlines part of what is required

Still have a range of outstanding challenges for SoSE

Managing the Complexity of SoSE

- SoS variety and relations
- Multiple scales
- Unmanageable documentation based SE processes at SoS scale
- architecture management
- Knowledge management
- effective orchestration & coordination
- accountability management
- Nested concepts purposes
- Multidisciplinary view of SoS



Monitoring the 'Well Being' of SoS

- Current
- Evolving
- From multiple perspectives

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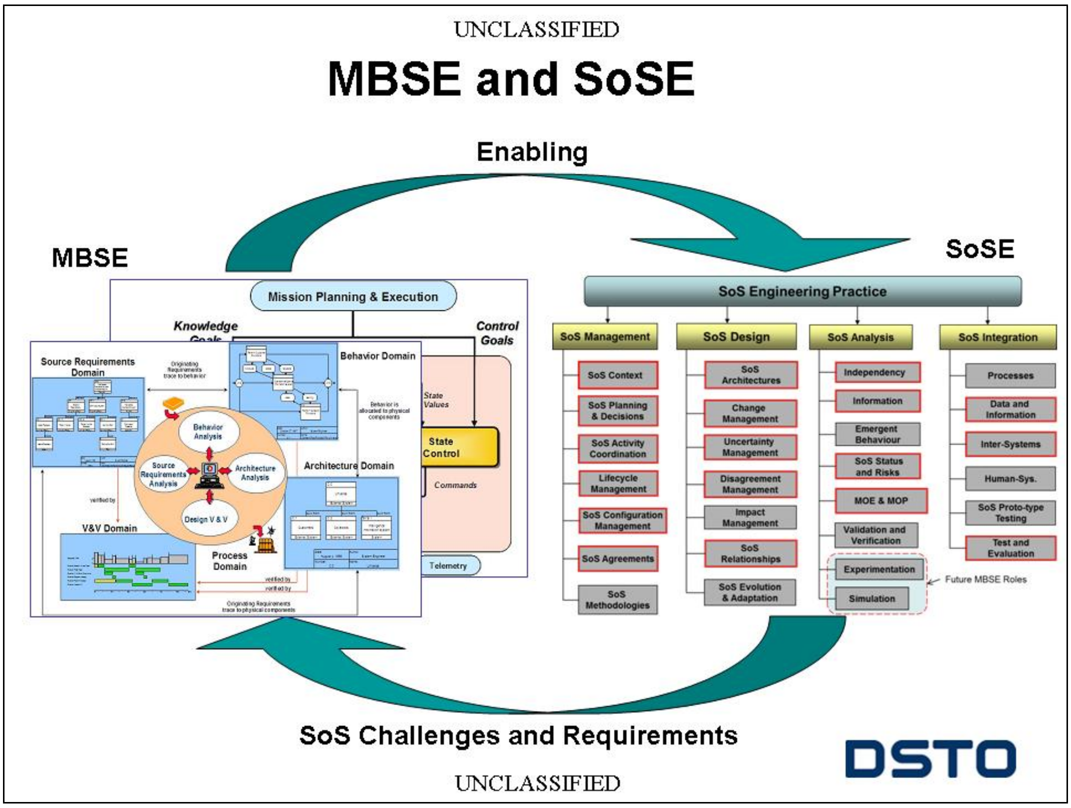
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MBSE and SoSE
Enabling
MBSE
SoSE
Mission Planning & Execution
Knowledge Goals
Control Goals
Source Requirements Domain
Behavior Domain
Behavior Analysis
Source Requirements Analysis
Architecture Analysis
Design V & V
Architecture Domain
State Values
State Control
Commands
Telemetry
V&V Domain
Process Domain
SoS Engineering Practice
SoS Management
SoS Design
SoS Analysis
SoS Integration
SoS Context
SoS Planning & Decisions
SoS Activity Coordination
Lifecycle Management
SoS Configuration Management
SoS Agreements
SoS Methodologies
SoS Architectures
Change Management
Uncertainty Management
Disagreement Management
Impact Management
SoS Relationships
SoS Evolution & Adaptation
Independency
Information
Emergent Behaviour
SoS Status and Risks
MOE & MOP
Validation and Verification
Experimentation
Simulation
Processes
Data and Information
Inter-Systems
Human-Sys.
SoS Proto-type Testing
Test and Evaluation
Future MBSE Roles
SoS Challenges and Requirements
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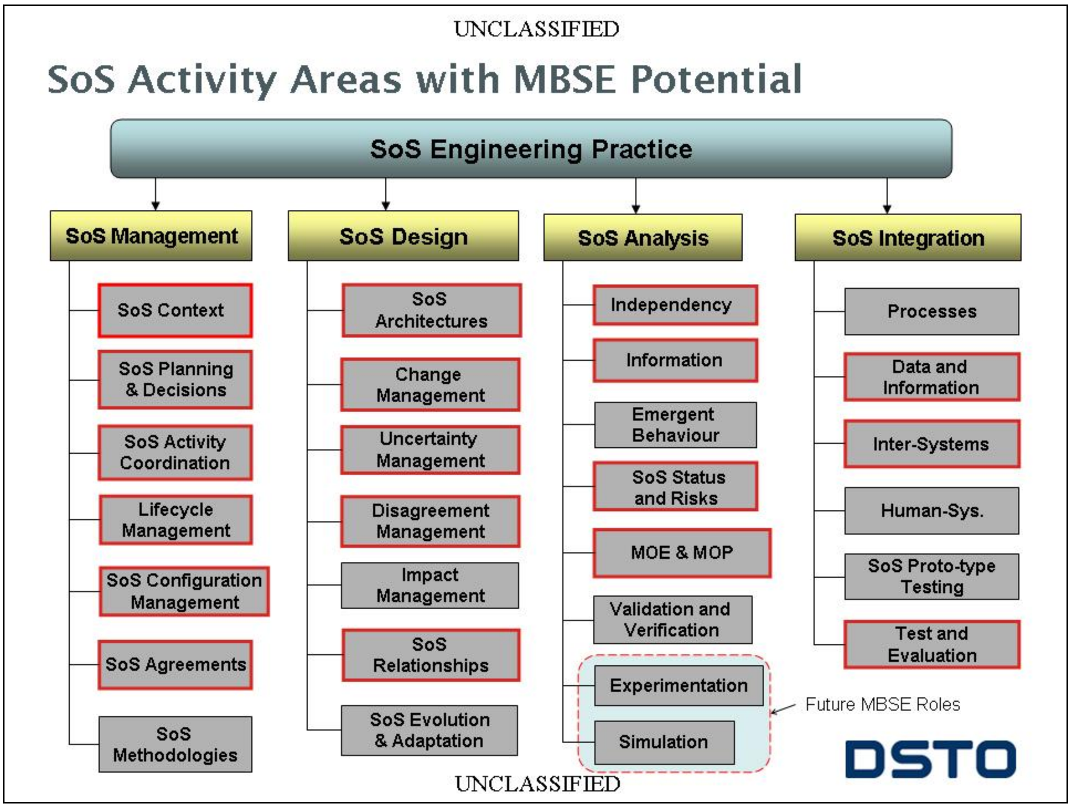
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SoS Activity Areas with MBSE Potential
SoS Engineering Practice
SoS Management
SoS Design
SoS Analysis
SoS Integration
SoS Context
SoS Planning & Decisions
SoS Activity Coordination
Lifecycle Management
SoS Configuration Management
SoS Agreements
SoS Methodologies
SoS Architectures
Change Management
Uncertainty Management
Disagreement Management
Impact Management
SoS Relationships
SoS Evolution & Adaptation
Independency
Information
Emergent Behaviour
SoS Status and Risks
MOE & MOP
Validation and Verification
Experimentation
Simulation
Processes
Data and Information
Inter-Systems
Human-Sys.
SoS Proto-type Testing
Test and Evaluation
Future MBSE Roles
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MBSE Support and SoS Perspectives

Platform Based SoS

- Similar to standard major project SE use of MBSE
- "Imperial projects" taking lead for major elements of SoSE

System based SoS

- Networking / Information system "glue" projects
  - Generally Virtual or Collaborative but moving to Acknowledged SoS
- MBSE to support engineering & management support across many projects
- High impact, particularly for Joint and Land

Capability based SoS

- CDG/DMO SoS and service based SoS
- MBSE to support SoS synthesis and engineering of multiple component projects
  - Managing and applying lessons learnt
  - Generally Virtual or Collaborative SoS management, some Acknowledged SoS

Force based SoS

- Potential to use MBSE to support force design trade-offs (?)

Operational based SoS

- Directed SoS, but with little engineering design
  - Potential to use MBSE to support force design trade-offs
- MBSE has a role in configuration control and certification

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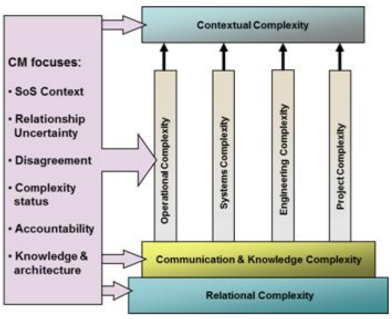
MBSE Support to SoS Complexity Management

Need an integrated SoS approach

- Cross project knowledge
- Managing the volume of data
- Common methodology



MBSE provides potential to:

- Establish SoS standards and processes
  - Generate consistent component artefacts
  - Enable synthesis of SoS artefacts
- Manage web of cross-project
  - Interdependencies
  - Agreements
- Support SoS design trade-offs
  - Central tool for managing each 'SoS Wave'
- Monitor & manage SoS status and Well Being
- Manage and track status of large numbers of component systems
- Understand impact of changes from component systems on SoS

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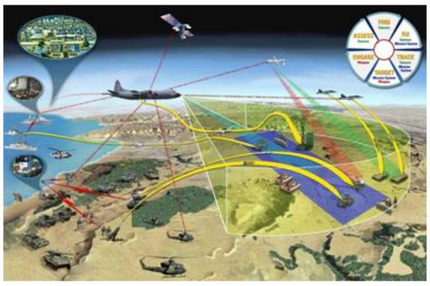
Building Upon Exiting Defence SoS Communities

Defence has established SoS Capability communities
(but currently with only limited examples with SoSE), such as:

- Joint Fires
- Joint ISR
- Amphibious
- Base Protection
- Counter IED'
- Force Networking (Glue)
  - Particularly Tactical Land Force Networking



Seek to build on these communities and add the missing SoSE component

Complexity necessitates an MBSE based approach

- Requires development of MBSE tools and stakeholder education

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Challenge for MBSE Community

Build the MBSE tools, processes & practices for SoSE

Start applying MBSE to key SoS test cases:

- Amphibious Capability
- Land Force Networking
- Certification of Operational Forces

Establish a partnership with capability development community for SoSE

- Note also called "capability engineering"

Time is right to address SoSE

- Lessons from large projects have grow the need for capability engineering
- Initiatives in CDG – DGICD to address

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Conclusion

SoS present a major challenge for Defence engineering
- Complex, with a large number of component systems
- Different from traditional SE
  - Often enduring systems developed in 'Waves'
- Multiple Perspectives on SoS

Need MBSE in order to:
- Establish SoS standards and processes
- Manage the volume of SE artefacts
- Manage web of cross-project Interdependencies & Agreements
- Support SoS design for each 'SoS Wave'
- Monitor & manage SoS status and Well Being
- Understand impact of changes from component systems on SoS

Window of opportunity to establish a MBSE in Defence SoSE

Initially address a few test cases:
- Amphibious Capability
- Land Force Networking
- Certification of Operational Forces

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14. Model Based Systems Engineering: Issues of application to Soft Systems

Ady James, Alan Smith and Michael Emes
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Abstract

Projects often seek to deliver new or improved capabilities within complex, poorly defined and changing contexts. The application of MBSE under such circumstances can be problematic and in this paper we discuss these issues, and suggest approaches for their mitigation.

A particular system solution might be envisaged as a combination of subsystems connected through a common architecture. Systems thinking suggests that given clear requirements and a solution concept, one can move forward through the definition of subsystem capabilities and the system architecture – where MBSE is particularly useful. However, in many applications the degree of turbulence or evolution within the requirements that can be expected means that close human intervention is necessary to keep the solution fit for purpose. Moreover, this human intervention must be based on significant experience and domain knowledge so as to cope with the many Soft System issues that are likely to be present. At University College London (UCL) Centre for Systems Engineering we propose five principles that we believe should underpin all SE development projects. In this work we discuss these principles and their application to MBSE within a Soft System context.

The UCLse principles are:

- Principles govern process
- Seek alternative systems perspectives
- Understand the enterprise context
- Integrate systems engineering and project management
- Invest in the early stages of projects

Moreover, we will also look at how encapsulation can be used to protect MBSE sub-system developments from the likely changes in scope and direction of the overall development. Encapsulation, while fundamental to an object oriented approach, is much less well developed for soft systems projects except where it manifests as a pragmatic approach taken by the systems engineer, systems engineering manager or project manager. Through an encapsulation approach one can create a system from the inside out, i.e. begin sub-system development before the final structure of the overall system is fully defined. There are parallels with a system-of-system approach in which the sub-systems pre-exist the system. Re-use and the use of Commercial-Off-The-Shelf (COTS) and Military-Off-The-Shelf (MOTS) sub-systems are natural to an encapsulated approach.

An important element of such an approach is the validation of the chosen system architecture or an estimation of its resilience. This can be undertaken through a carefully selected (and weighted) set of scenarios – the consequences of each being used to define the interface margins and architectural capacity within the overall system. This is a natural extension to the concept of requirements volatility found in requirements management tools etc.

Finally we will look at the bounds of MBSE, where is it *not* a practical way forward and where should it be supplemented and augmented by a Soft Systems front end and concurrent activity? For instance some system capability uplifts are dominated by the viewpoints of existing participants and are often in situations where there is no single design authority. While MBSE can improve their toolset, the actual system level changes that are possible may lend themselves more to change management than MBSE.

Presenter Biographies

Dr. Adrian James is a Senior Research Fellow at MSSL and Co-director of UCL Centre for Systems Engineering (UCLse). He has worked at UCL for more than twenty years on various space programmes, including Mars 96, Cluster, XMM Newton, Hinode, and most recently the ESA Euclid project. As well as his project management and systems engineering activities within the Department Dr James provides training courses to industry on various aspects of Systems Engineering and Project Management. He is now based in Adelaide as Executive Director of MSSL (Australia).

Professor Alan Smith started as an instrument scientist for the Medium Energy X-ray Experiment which flew on-board the European space agency mission EXOSAT. In 1990 he joined MSSL, initially as Head of Detector Physics but later to become Programme Manager and eventually Director and Head of Department and vice-Dean for Enterprise. In 1998 he was made a Professor of Detector Physics. While at UCL he has been Director of UCL's Centre for Advanced Instrumentation Systems, a Co-director of the Smart Optics Faraday Partnership and is founding Director of UCLse.

Dr. Michael Emes is Head of the Technology Management Group at MSSL and Co-director of UCLse. He researches technology management tools and theory, risk management, modelling, and the intersection of systems engineering and management. He teaches postgraduate courses at UCL and industrial training courses in the areas of systems engineering, design, modelling and management. Before joining UCL, Michael was a strategy consultant working on projects in retail, e-commerce and transport. He has a first-class MEng in Engineering, Economics and Management from St. John's College, Oxford, and a PhD in Spacecraft Engineering from UCL.

Presentation

Model Based Systems Engineering – Issues of application to Soft Systems

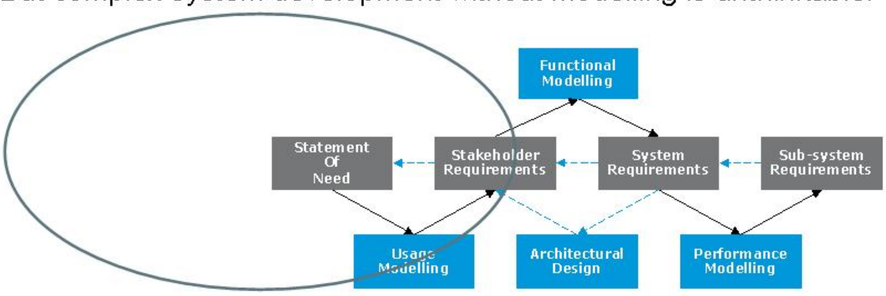
Professor Alan Smith
Dr Adrian James
Dr Michael Emes
Centre for Systems Engineering
University College London, UK

But what is MBSE?

INCOSE SE Vision 2020 (INCOSE, 2007):

"the formalized application of modelling to support systems requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later lifecycle phases".

But complex system development without modelling is unthinkable.



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MBSE for soft systems

Let's avoid a debate here about what MBSE is and how it differs from 'Conventional SE'

Maybe the devil's in the 'formal' bit.

- Instead let's consider:
  - Hard and Soft Systems
  - Application of UCL's principles for systems engineering
  - Scenarios
  - Encapsulation

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Hard and Soft Systems

Soft system element (person or team)

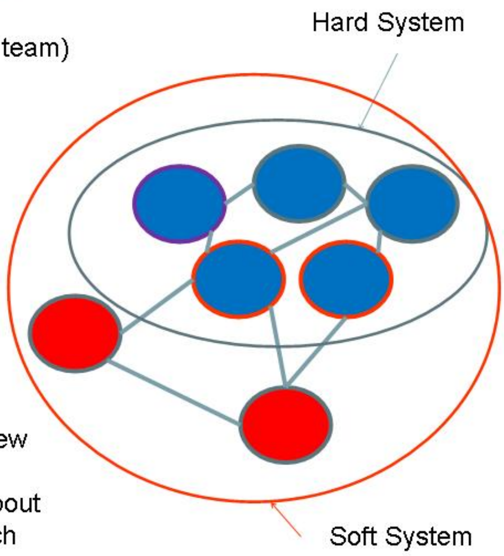
Hard system element

Hard system element with HCI

Hard System requirements come from Soft System needs

For instance a capability of a warship only comes about when you add the crew

Dealing with Soft Systems is not just about HCI or Human Factors but includes such elements as buy-in, legacy thinking, cultural change, ...



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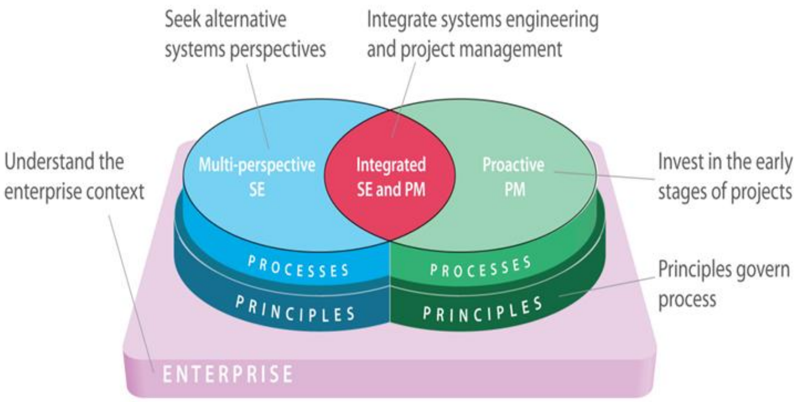
UCL Centre for Systems Engineering Principles of Systems Engineering



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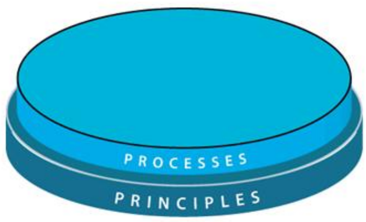
Principle 1 – Principles govern process

- When **adapting a generic process** to a particular situation the individual must first **understand the principles that underpin the process**.
- In Soft Systems it is very important to understand the human dimension. While the systems development principles will be common to Hard and Soft, the application will not.
- For instance a requirements capture process for a Hard System could be very different to that of a Soft System. Similarly for requirements validation or verification etc.
- The application of MBSE to Soft Systems will require skilful application by the system engineer. Not someone with a tool and a handbook.



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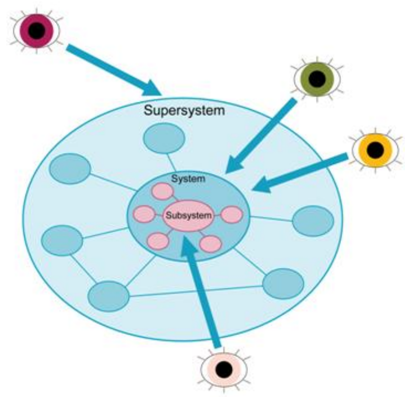
Principle 2 – Seek alternative systems perspectives

- The very essence of Soft Systems development and natural to Model Based Structured Analysis and Design Methodologies.
- MBSE should explore a range of systems perspectives, viewpoints or abstractions to enhance understanding. It should not be confined to just structure, and behaviour models.
- The time dimension can be a valuable source of insight.
  - Not just operational sequences and timelines but also heritage (which informs buy-in) and foresight
- Recognise the importance of overlapping hierarchies
  - Elements that are parts of more than one system require appropriate management.



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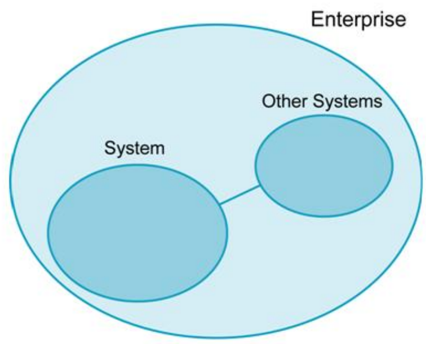
Principle 3 – Understand the enterprise context

- In Soft System developments the separation between the system and its environment is often fuzzy while in MBSE its either technological or a HCI/GUI.
- Taking a 'Seven Samurai' approach then the Enterprise is just an other system (Soft) within the system landscape.
- The accommodation of Soft System often faces many diverse constraints from the Super System.
- In Soft Systems lack of corporate buy-in and end user understanding are more common causes of failure than technical issues.



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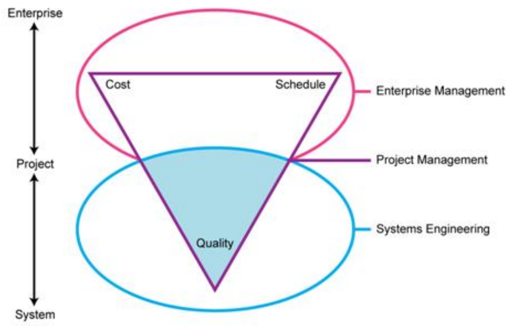
Principle 4 – Integrate Systems Engineering and Project Management

- While PM's tend to use many simplistic and deterministic tools (e.g. Gantt charts) nevertheless they are dealing with an essentially Soft System where human management is necessary.
- Systems Engineers work with relatively deterministic tools and processes.
- Everyone is seeking models that are understandable and useful
- The efficacy and efficiency of such models in Soft System developments are likely to be quite different to that of Hard Systems developments.



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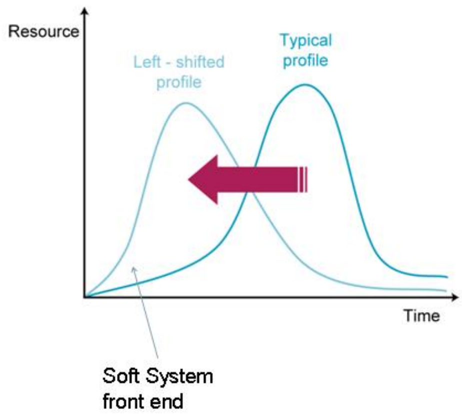
Principle 5 – Invest in the early stages of projects

- For any activity in a project there will be a correct time to undertake it.
  – Too early wastes resources while too late can lead to downstream adverse impacts.
- The optimum ordering of activities should be identified, resisting pressure to defer work until later for short-term reasons.
- A Soft System front end which creates a more stable requirement set could be a good investment for many developments which are, eventually, suitable for a more formal MBSE approach.



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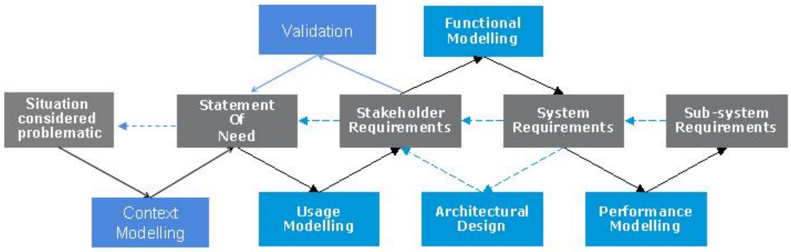
Soft System Front End



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Agile?

- Agile accommodates many of the issues typically found in Soft Systems (such as evolving needs and stakeholder requirements) through an iterative and rapid lifecycle that includes user feedback.
- However, is Agile something that makes up for the absence of an effective Soft System front end?
- Should Agile be adapted to be more 'left shifted', in which much of the requirements evolution is dealt with up front.

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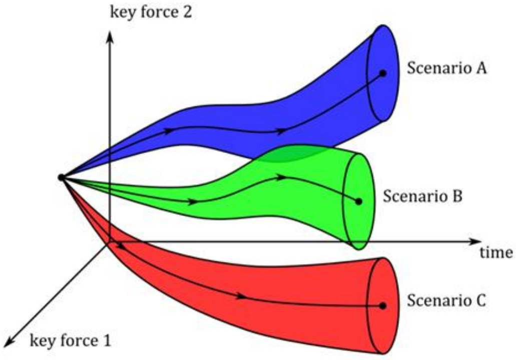
Scenarios Planning / Requirements Validation

- In Soft System project stakeholder requirements are likely to evolve during the development of the systems and after.
- The baseline requirements set must somehow anticipate these changes
- Through the use of scenario planning these requirements can be tested for robustness
- MBSE projects with significant soft system aspects should engage in scenario planning as part of requirements definition and validation.



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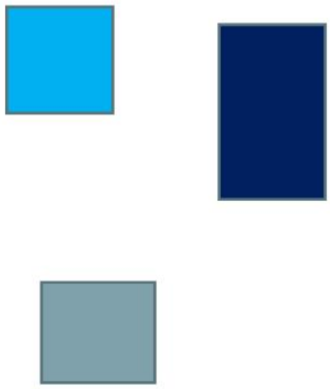
Encapsulation

- Soft system elements may begin as very well defined structures



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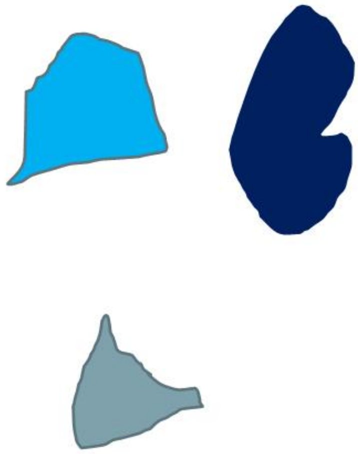
Encapsulation

- But they have a habit of evolving in an uncontrolled way



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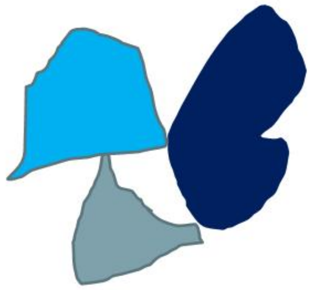
Encapsulation

- This makes for downstream incompatibility



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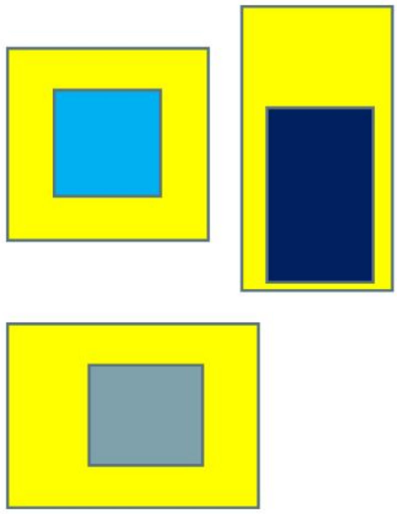
Encapsulation

- However if you surround your systems elements within a standard interface



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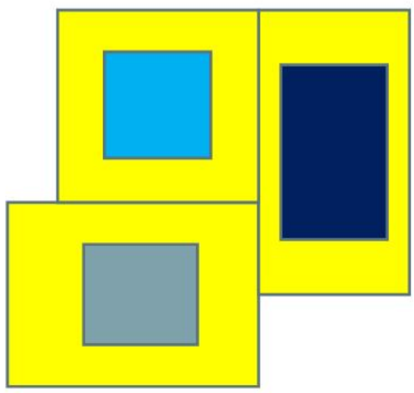
Encapsulation

- Their integration is more assured
- They are more easily tested



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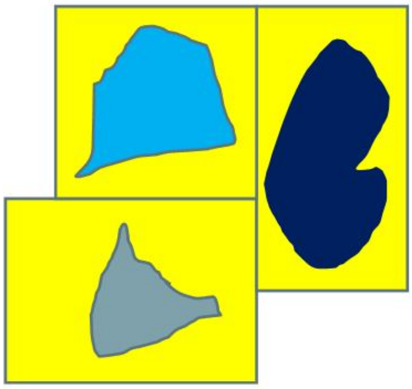
Encapsulation

- And they will continue to be integrated even as they evolve
- Scenario Planning can inform the ‘thickness’ of the encapsulation.



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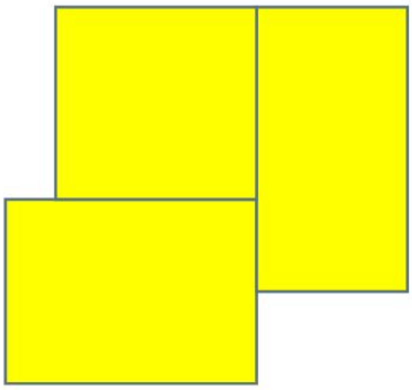
Encapsulation

- After all a systems architect is mainly interested in what’s inside the elements, only what the element does.



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Encapsulation

- Soft Systems Encapsulation is another left-shifted activity.
- It includes:
  - Robust organisational structures
    - E.g. robust against corporate reorganisation
  - Robust cultures
    - Taking advantage of a human characteristic, albeit at the risk of downstream inflexibility
  - Robust job descriptions
    - Titles reflect the role, e.g. 'Systems Engineer'
  - Robust tool sets
    - That do not change with every upgrade

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Conclusions

- Hard and Soft systems are related. Often the Hard Systems requirements have their origins in a Soft System.
- Soft Systems developments use models too, only different models.
- A hybrid lifecycle could be imagined with a Soft System front end.
- If we are to imagine a hybrid lifecycle we need better front end tools.
- E.g.:
  - Rich Picture analysis tools that create influence diagrams, entity relationship diagrams etc.
  - Scenario Planning tools that can be used to validate Soft Systems requirements

- Of course it would be nice to know what MBSE really is.

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15. Best of Both Worlds: CORE-based WSAF with DOORS-based Requirements Management

Roger McCowan[1] and Michael Waite[2]
[1]MHW Holistic Solutions and [2]Aerospace Concepts

Abstract

The Whole-of-Systems Analytical Framework (WSAF) has been developed at DSTO with personnel from both Weapons Systems Division (WSD) and Aerospace Concepts Pty Ltd. It is based on Vitech CORE® and has evolved and matured through use on several projects and proved its worth as an MBSE capability environment. Despite the successes of the WSAF and the functionality within CORE® to support requirements management, Defence policy currently remains that IBM® Rational® DOORS® is mandatory for the requirements management on all ACAT I and ACAT II projects. Because of the Defence Materiel Organisation's (DMO) current investment in DOORS® (licences and number of people trained in its use, etc.) this situation is unlikely to change for some time.

This paper provides an overview of the means by which the capability modelling can be done using the WSAF to maintain model integrity whilst allowing projects to perform the ongoing management of requirements using DOORS®. The approach was developed and refined during the definition of the Land Combat Vehicle System (Defence Project LAND400), where the Operational Concept Document had been developed using the WSAF, and three Function and Performance Specifications (FPSs) covering nine vehicle variants needed to be produced using the WSAF but with the requirements transferred into DOORS® for use by the DMO project office.

In order to maintain consistency between the two databases a strict data management scheme was developed, including the definition of the data interface. One of the greatest challenges of this was to understand and overcome the different implementations of data attributes and relationships used in CORE® and DOORS®. Amongst the variety of information transferred through this interface was the unique identifier assigned in both software tools to ensure data veracity. Although many of the requirements were common across both the three main vehicle types and the nine vehicle variants, there were others which were unique to particular variants. This highlighted the strength of the model-based approach, where it was possible to update the detail of one requirement, which would be reported in all relevant specifications.

While the process developed and implemented still required manual "post-processing" of some of the data (mostly resulting from the differing character sets for hard returns, non-breaking spaces and special characters e.g. °, ±, etc), this work proved that the systems engineer really can have the "best of both worlds" – the strength of rich, model-based information architecture from CORE® and the benefit of rigorous requirements management from DOORS®.

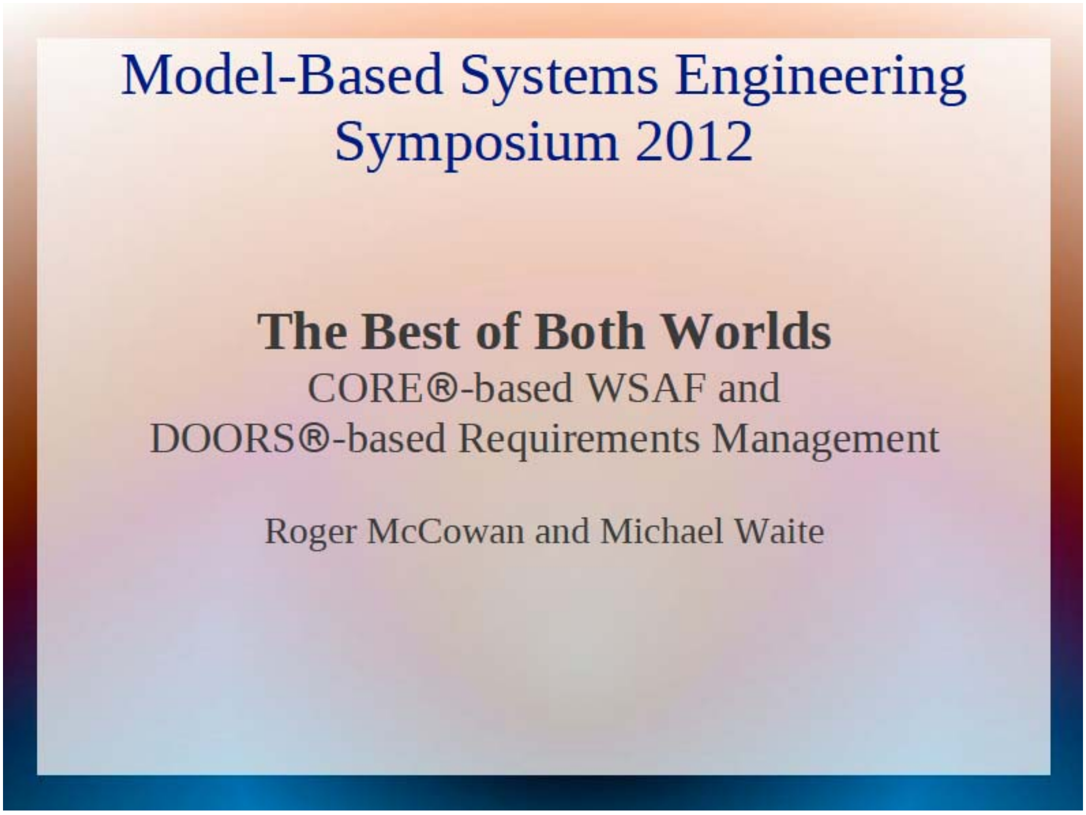
This presentation will provide insight into the CORE® to DOORS® interface developed, the challenges faced and advice to personnel engaged on major capital equipment projects – in particular, they should not use the mandated policy of DOORS-based requirements management as an excuse to not use the WSAF to do capability modelling.

Presenter Biographies

Mr Roger McCowan, BEng(Communications) is a senior Systems Engineer whose professional experience spans more than thirty years during which he has specialised in systems engineering across both the Defence and commercial sectors. He has extensive experience in requirements definition and analysis, system specification, architecture design, verification and validation, and project management, with a focus on networked information systems. He has published several papers in these fields.

Mr Michael Waite, BEng(Mechatronics) has been working as a professional engineer for over ten years since completing his Bachelor of Engineering (Mechatronics) degree in 2001. His career has seen him working for several multi-national automotive companies in Australia, Asia and Europe, including Mitsubishi Motors, Ford and Caterpillar. He currently works for Aerospace Concepts, a systems engineering consulting company, specialising in the development of complex-system capabilities.

Presentation



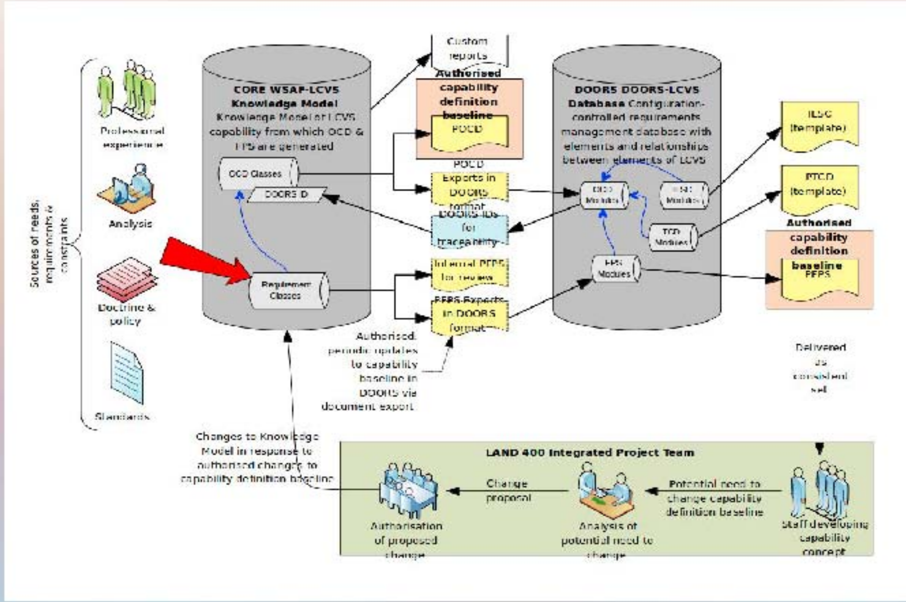
Overview of Presentation

- Project Context
- Approach
  - Strict data management scheme
- Interface
- Challenges
- Method/Process
- Conclusion
- Q & A

Project Context

- Land Combat Vehicle System (LAND400)
  - OCD developed during 2011 using WSAF
  - DMOSS Contract in 2012 to develop three FPSs covering nine vehicle variants
  - FPS requirements to be in DOORS® as per DMO policy
  - DMO Project Office/LEA provided SME and drafted many of the requirements using Excel

Approach



Interface (1)

- Single CSV file, exported from CORE®
- Fields
  - Vehicle Variant (Defined list, multi-valued)
  - DOORS Requirement ID
  - CORE Object ID
  - Requirement Text
  - Requirement Priority (Defined list)

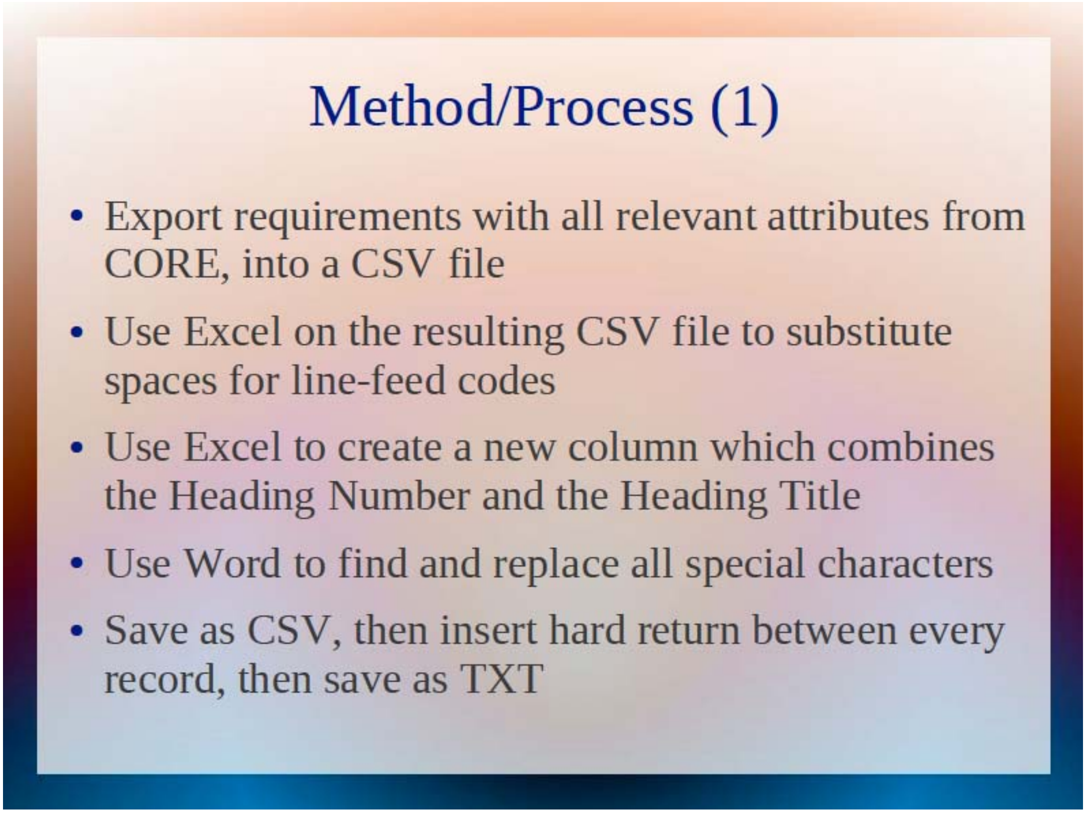
(continued on next Slide)

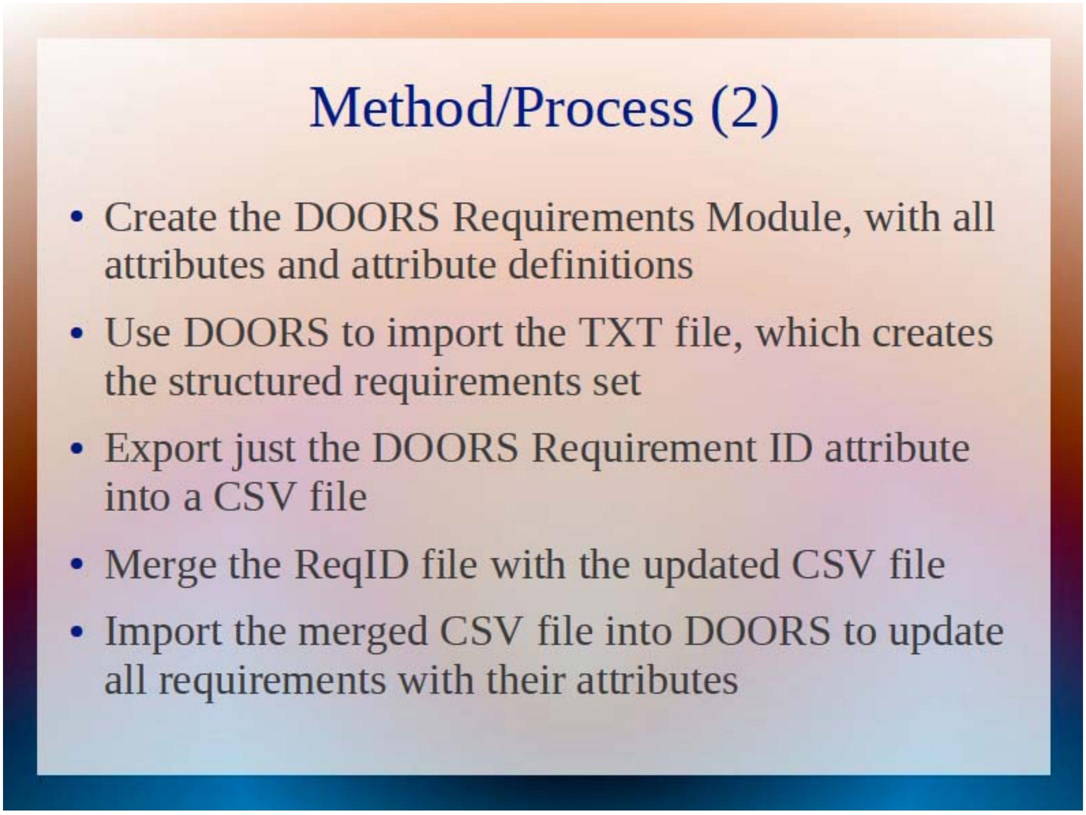
Interface (2)

- Fields (continued)
  - Verification Method (Defined list, multi-valued)
  - FPS paragraph reference (in accordance with the FPS DID)
  - Rationale
  - OCD cross-references

Challenges

- Requirement Text copied from Excel cells contained embedded line feed codes (char(10)), as well as non-breaking spaces
- CSV exported from CORE loses diagrams and formatting information (superscript, bold, etc.)
- DOORS importation of CSV file could not handle special characters (e.g °, ±, smart-quotes, and non-breaking spaces)
- Attribute Definitions – mismatches will cause importation to fail


Method/Process (1)
• Export requirements with all relevant attributes from CORE, into a CSV file
• Use Excel on the resulting CSV file to substitute spaces for line-feed codes
• Use Excel to create a new column which combines the Heading Number and the Heading Title
• Use Word to find and replace all special characters
• Save as CSV, then insert hard return between every record, then save as TXT


Method/Process (2)
• Create the DOORS Requirements Module, with all attributes and attribute definitions
• Use DOORS to import the TXT file, which creates the structured requirements set
• Export just the DOORS Requirement ID attribute into a CSV file
• Merge the ReqID file with the updated CSV file
• Import the merged CSV file into DOORS to update all requirements with their attributes

Method/Process (3)

- In DOORS, perform find/replace on special characters
- Perform manual update of text with superscripts
- Insert diagrams and figures at appropriate places and levels
- Export CSV file from DOORS to update CORE with DOORS ReqIDs

Conclusions

- The process steps described took about one hour, on a requirement set of about 1800 requirements
- The WSAF CORE model remains the “Source of Truth” at all times, therefore changes are NOT made to the DOORS requirement objects
- Revisions are best done by replacing the DOORS requirement module, rather than updating attributes
- CORE®-based WSAF and DOORS®-based Requirements Management is simple and viable

16. A Formal Modelling Language Extending SysML for Simulation of Continuous and Discrete System

Mark Hodson[1] and Nick Luckman[2]
[1]Block Software and [2]Weapons Systems Division, DSTO

Abstract

MBSE tools and techniques in a broad sense provide a structured approach to developing conceptual models of complex systems. Key features of these approaches are: the use of graphical based views on a central model that reflect the interests of particular stakeholders in the system; hierarchical decomposition of the system in question; and an ability to add, over time, increasing levels of detail to the model as knowledge is acquired, or in other words allow the model to move from the abstract towards the formal without the need to redefine the model in a different modelling environment. Through such an approach the leap of faith required to transition from model to real system is reduced when compared to traditional techniques.

When the real world system is software it is possible to take the conceptual modelling methodologies all the way to a formal (in the mathematical sense) specification such that ultimately the model has a one to one mapping with the real software system. Indeed great strides have been made with modelling methodologies and tools in the software domain, for example with UML.

Systems Engineering of course has to deal with complex application domains well beyond just software, where any model of the system will always be conceptual at some level because a one to one mapping with the real system will never exist. SysML is an extension and modification of UML that aims to support the broader modelling needs of SE, hence the term MBSE. However, engineering has at its disposal another type of modelling that is simulation, which can provide great insights into the behaviour of complex systems. Although UML and SysML primarily support conceptual modelling they do have enough formality in them to support certain types of simulation (after all computer based simulations are in themselves software systems), for example in some behavioural graphical views, such as activity and state machine diagrams. The algorithmic model of computation used with these is basically Discrete Event Simulation (DEVS) such that the transitions between activities or state represent discrete events in time. Although many systems can adequately be simulated with discrete events (in time) many more need more powerful models of computation such as discrete time and Ordinary Differential Equation (ODE) solving, which although can be expressed in the DEVS formalisms are generally only realised in specialised engineering level, graphical based, modelling and simulation tools such as Simulink®. Such tools are built principally first and foremost to create formal models in a bottom up approach and thus lack features to support for conceptual modelling.

Interestingly the diagrams used in specialised engineering M&S tools often have the appearance of structural models. This is because they are actually graphical representations of mathematical algorithms, more precisely iterative algorithms. The challenge therefore for MBSE is to develop general purpose graphical modelling views that transition naturally from

system relevant decomposition views into views of iterative algorithms capable of being executed with potentially any iterative model of computation.

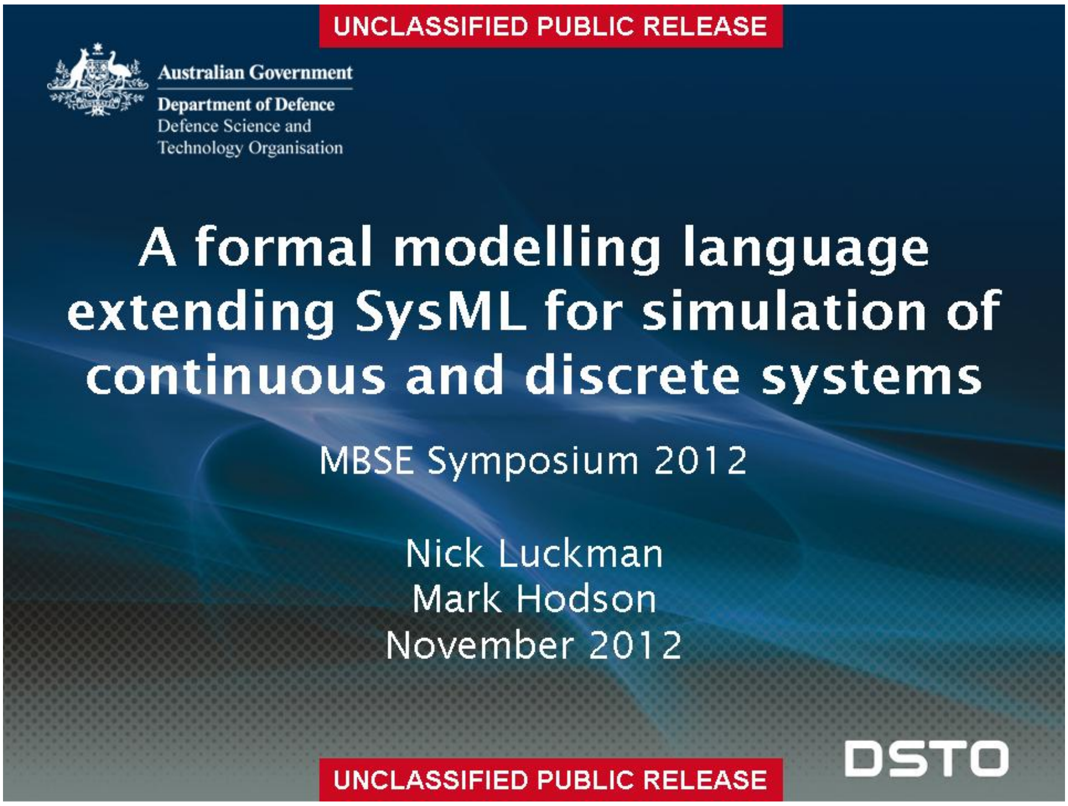
This paper outlines a graphical modelling view similar to the internal block diagram of SysML that supports hierarchical decomposition and iterative algorithmic expression at the same time.

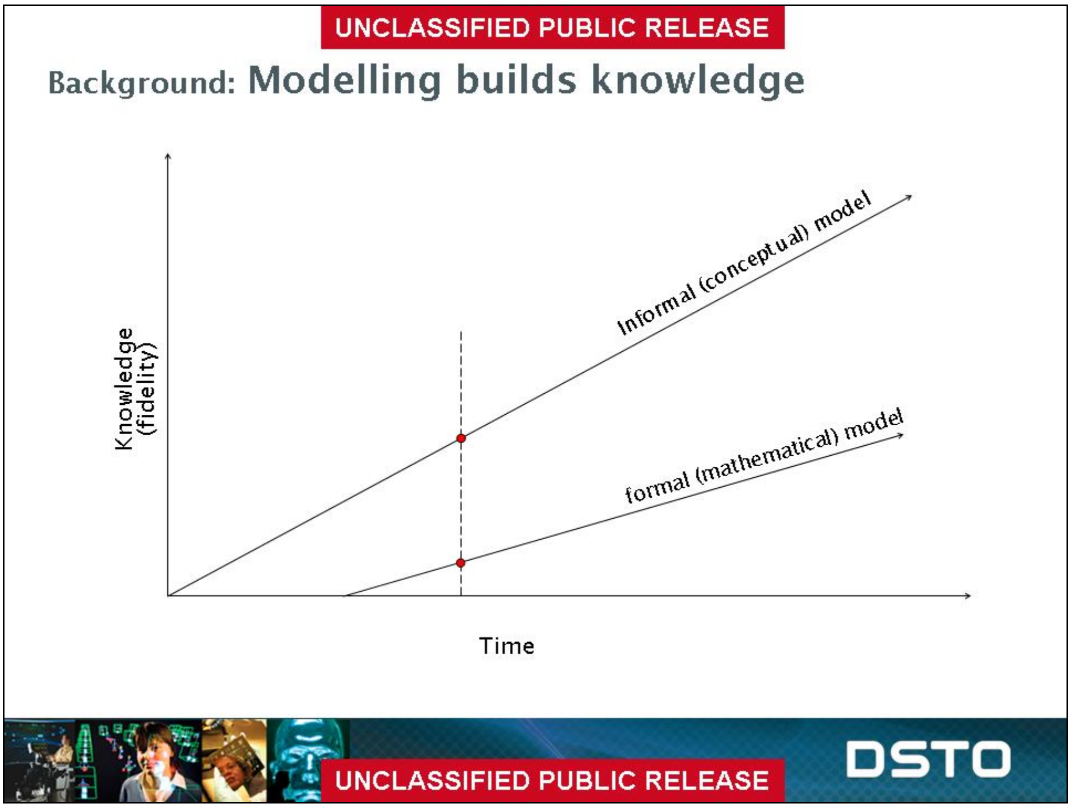
Presenter Biography

Mark Hodson graduated with 1st class honours in Computer Systems Engineering from Adelaide University at the end of 1999. Since that time, Mark has worked for Tenix Electronic Systems Division (formerly Vision Abell, now BAE Systems) in the areas of information security and hydrography, and has spent much of the last 10 years working on contract in Weapons Systems Division in DSTO in the areas of M&S theory and accompanying architecture development, collaborative vulnerability and lethality models, and providing software engineering support to specific tasks within the branch.

Nick Luckman graduated from Adelaide University in 1990 with a degree in Mechanical Engineering. Since then he has worked for the Defence Science and Technology Organisation working mostly on weapons systems. During this time he has developed many simulations with various levels of complexity and purpose. In the last seven years or so he has worked on developing modelling and simulation frameworks and architectures that take into account the business case of reuse.

Presentation

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Background: Modelling builds knowledge
Knowledge (fidelity)
Informal (conceptual) model
formal (mathematical) model
Time
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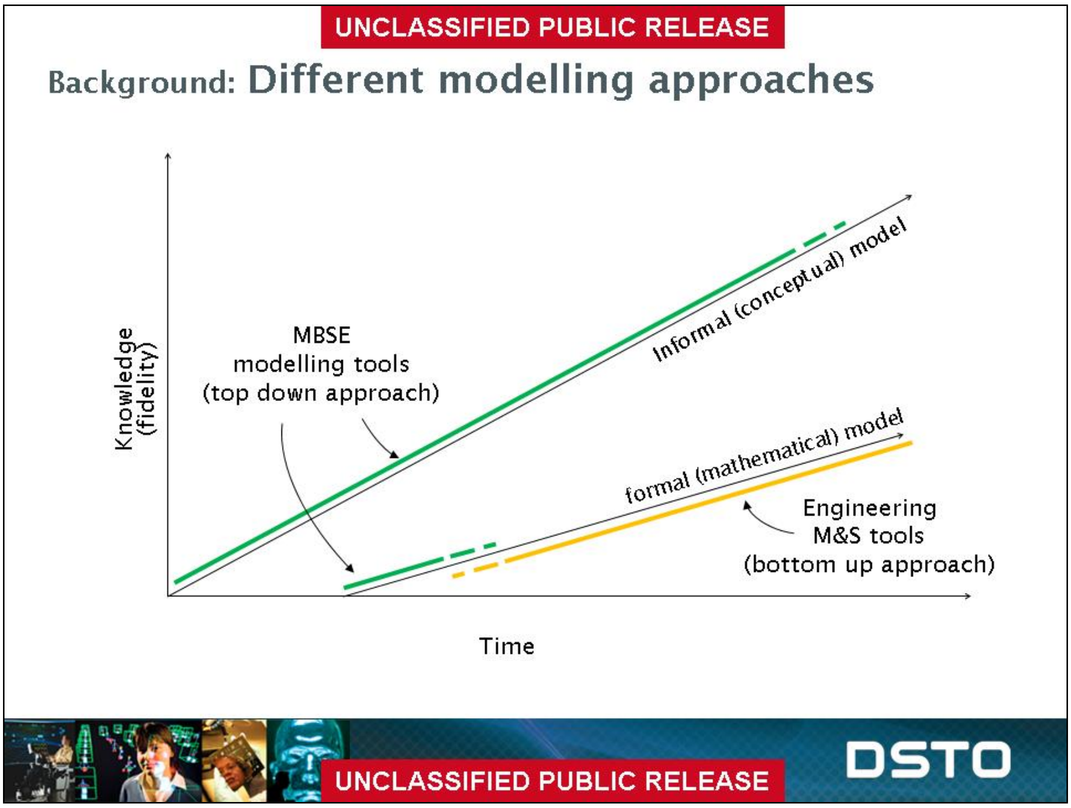
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Background: Different modelling approaches
Knowledge (fidelity)
MBSE modelling tools (top down approach)
Informal (conceptual) model
formal (mathematical) model
Engineering M&S tools (bottom up approach)
Time
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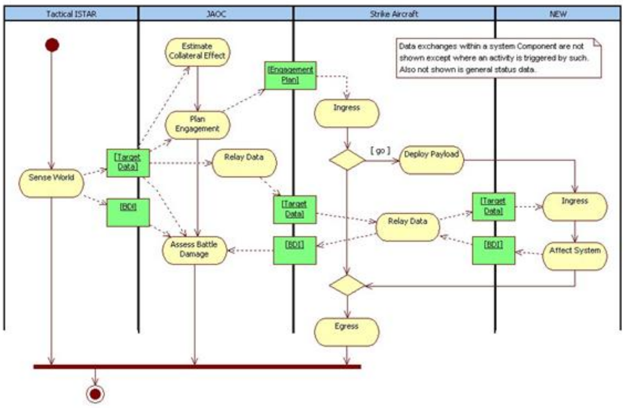
MBSE Approach to modelling behaviour



- Questions are around when the events occur.
- What about questions of a non-temporal nature?
- Either way it may be necessary to simulate the continuous-time behaviour of the system.

- The main elements represent constant behaviour for a period of time.
- Connections represent instantaneous transitions between different constant behaviours.
- This lends itself to simulating sequences of discrete events in time.

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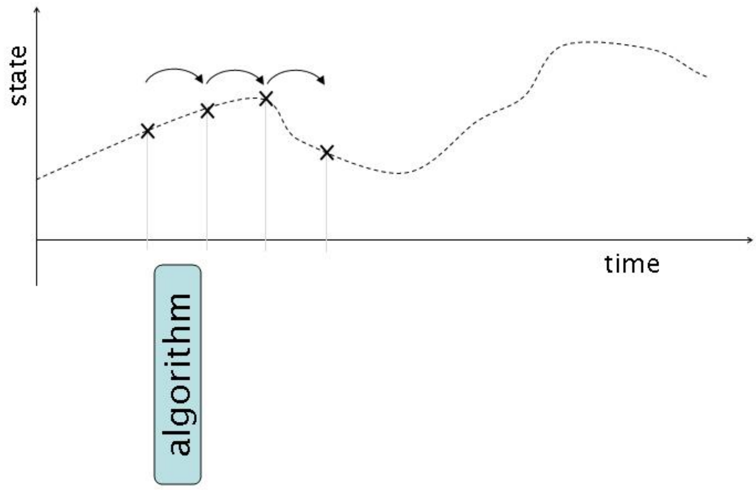
Traditional approach to modelling behaviour



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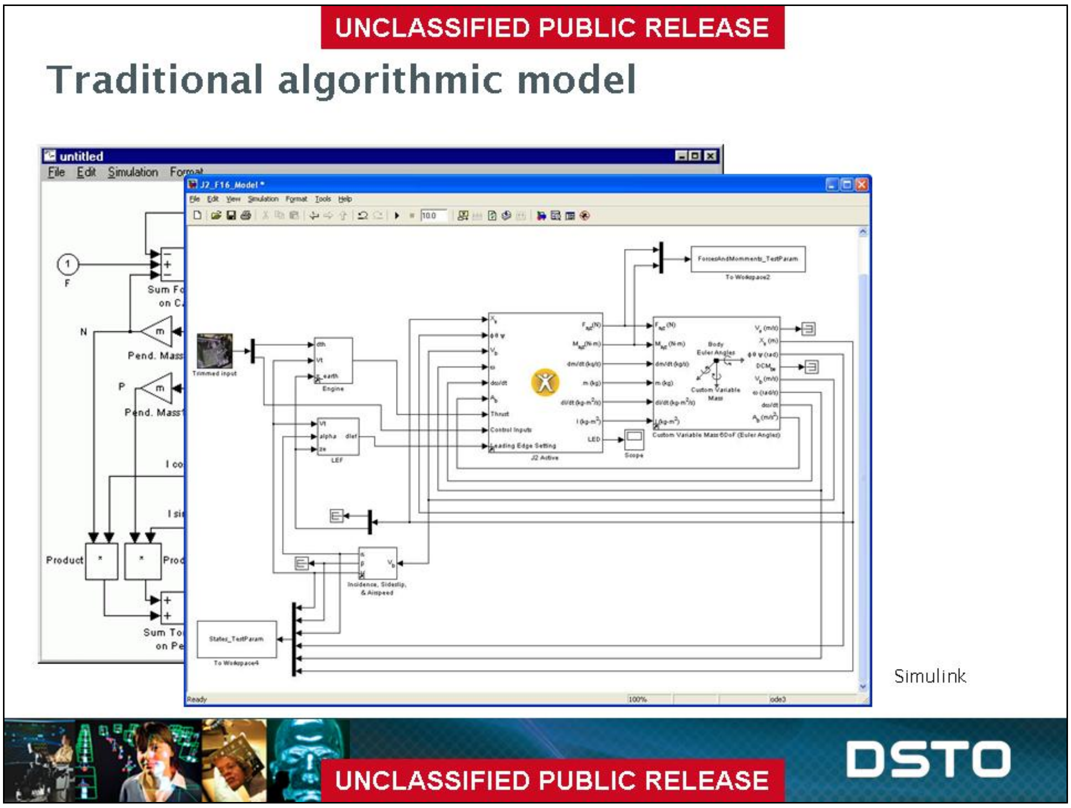
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Traditional algorithmic model
untitled
File Edit Simulation Format
J2_F16_Model *
Trimmed input
Engine
LEF
J2 Active
Scope
Custom Variable Mass 6DoF (Euler Angles)
Incidence, Sideslip, & Airspeed
States_TestParam
To Workspace4
ForcesAndMomments_TestParam
To Workspace2
Product
Simulink
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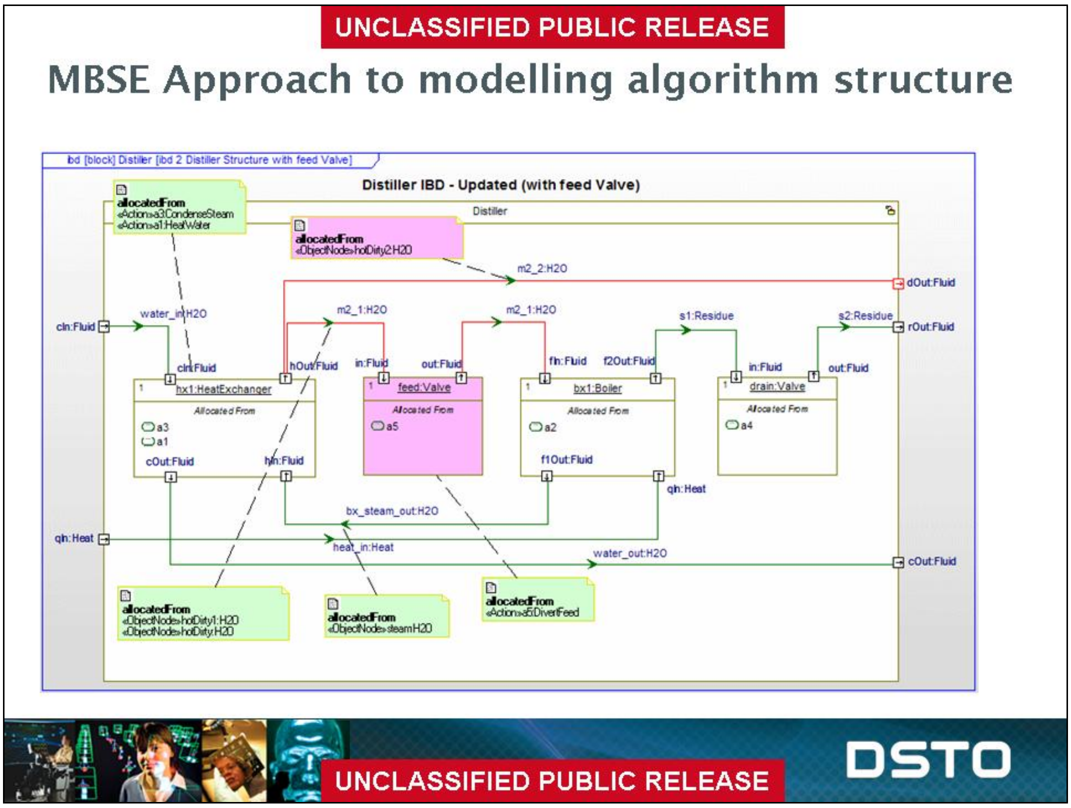
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MBSE Approach to modelling algorithm structure
ibd [block] Distiller [ibd 2 Distiller Structure with feed Valve]
Distiller IBD - Updated (with feed Valve)
Distiller
allocatedFrom
«Action»a3:CondenseSteam
«Action»a1:HeatWater
allocatedFrom
«ObjectNode»hotDirty2:H2O
m2_2:H2O
dOut:Fluid
cIn:Fluid
water_in:H2O
m2_1:H2O
m2_1:H2O
s1:Residue
s2:Residue
rOut:Fluid
cIn:Fluid
hOut:Fluid
in:Fluid
out:Fluid
fIn:Fluid
f2Out:Fluid
in:Fluid
out:Fluid
hx1:HeatExchanger
feed:Valve
bx1:Boiler
drain:Valve
Allocated From
a3
a1
a5
a2
a4
cOut:Fluid
hIn:Fluid
f1Out:Fluid
qh:Heat
bx_steam_out:H2O
qh:Heat
heat_in:Heat
water_out:H2O
cOut:Fluid
allocatedFrom
«ObjectNode»hotDirty1:H2O
«ObjectNode»hotDirty:H2O
allocatedFrom
«ObjectNode»steamH2O
allocatedFrom
«Action»a5:DivertFeed
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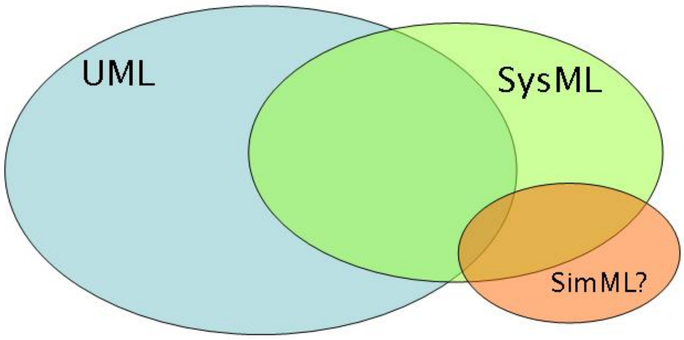
Proposed Solution



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Summary of Goals

- Seamless transition from systems decomposition to algorithm decomposition.
  - Both are structural views.
- Means of integrating multiple Models of Computation (MoC):
  - Discrete Event;
  - Discrete Time;
  - ODE solving;
  - etc
- Means of encapsulating MoC within branches of a model decomposition (MoC within MoC).

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Underpinning M&S Theory

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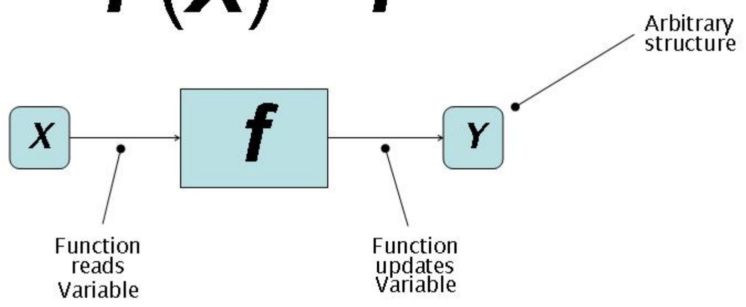
Mathematical Algorithms for Simulation

- Algorithms are formulated in terms of Variables and mathematic operations upon them (Functions).

$$f(X) \rightarrow Y$$



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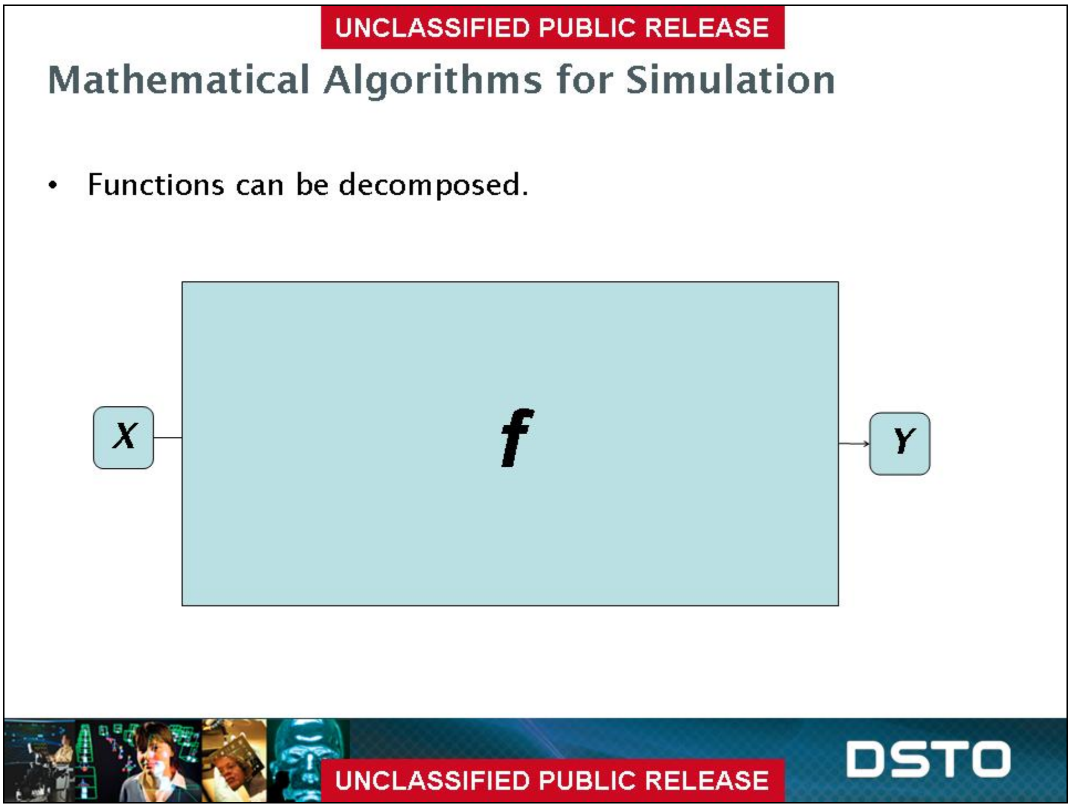
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Mathematical Algorithms for Simulation
• Functions can be decomposed.
X
f
Y
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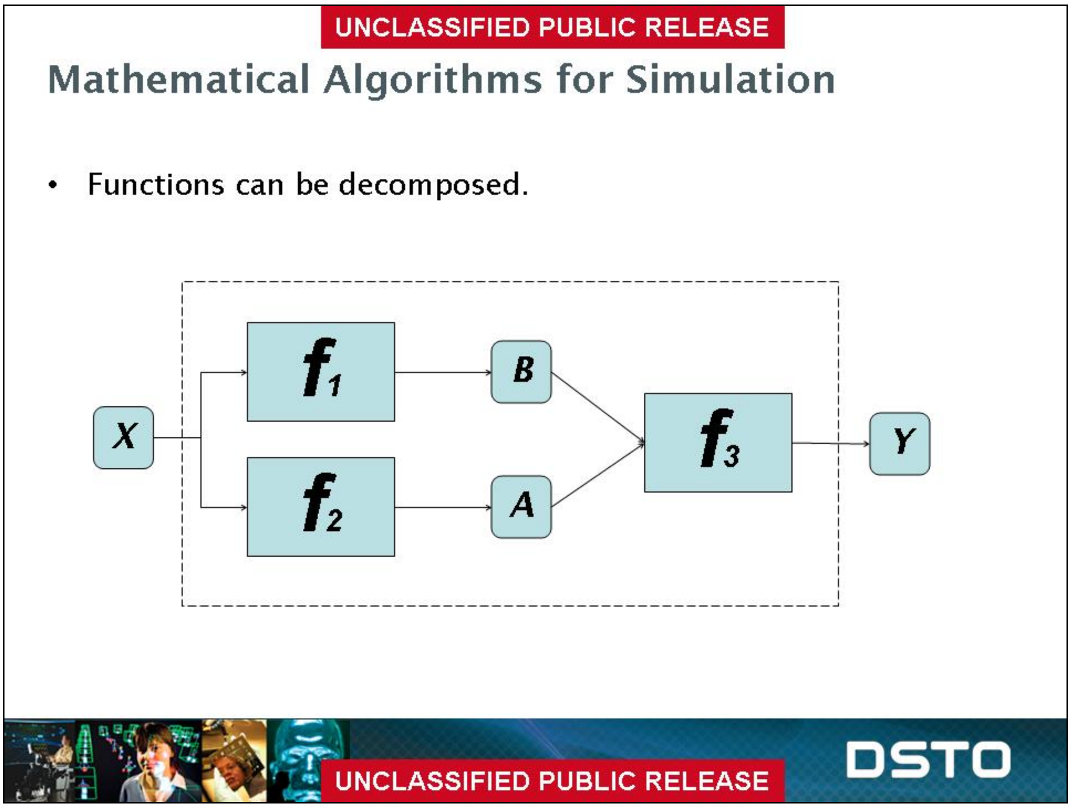
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Mathematical Algorithms for Simulation
• Functions can be decomposed.
X
f1
f2
B
A
f3
Y
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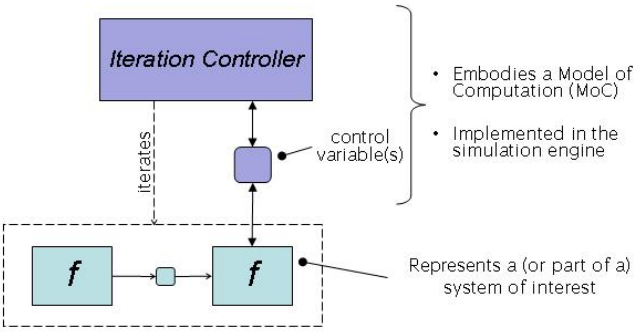
Mathematical Algorithms for Simulation

- Algorithms are iterative
  - Functions of the algorithm are executed in correct order once per iteration.



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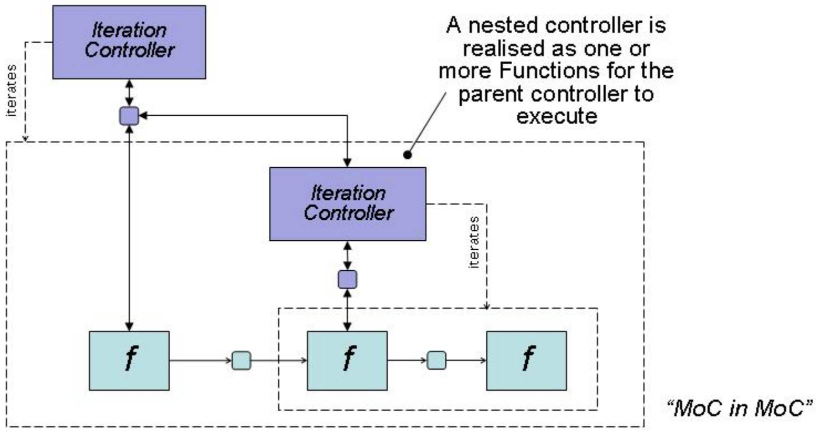
Mathematical Algorithms for Simulation

- Algorithm iterations can be nested.



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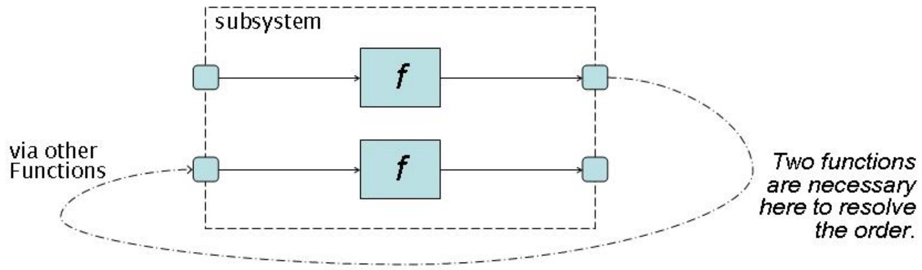
Issue

- The logical conceptual decomposition of a system will not in general map one to one with a mathematical algorithmic decomposition of it.
  - Some subsystems will need as a minimum more than one Function.



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Some Definitions

- A Function is a arbitrary collection of mathematics that can only be executed once all its input Variables have been properly updated in the context of the current iteration.
- A Variable is an arbitrary complex data structure that, within the context of an iteration, is updated and read by Functions.
- A Model of Computation is a set of rules regarding the execution and management of user declared Functions and Variables, and is implemented by an Iteration Controller.

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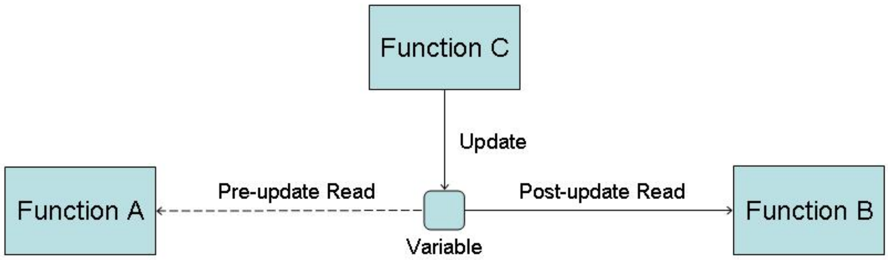
Iterative Algorithms



In the context of an iteration:

- Functions that read from a variable pre-update must be executed before it is updated.
- Functions that read from a variable post-update must be executed after it is updated.

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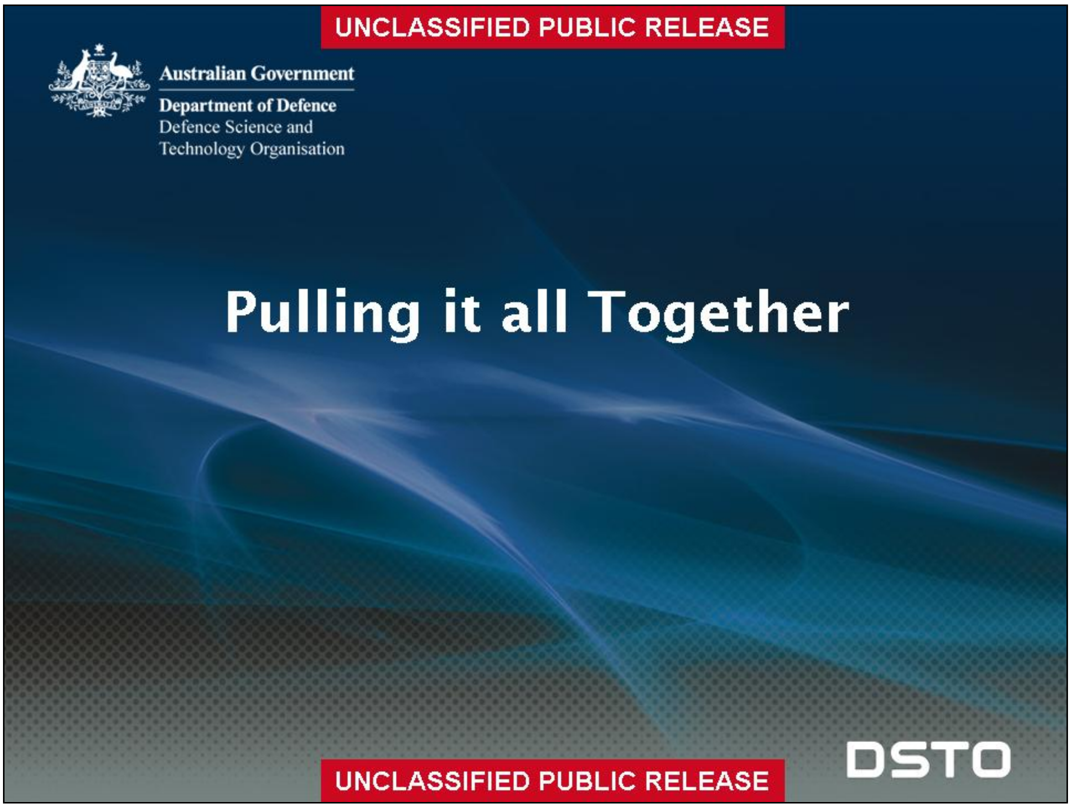


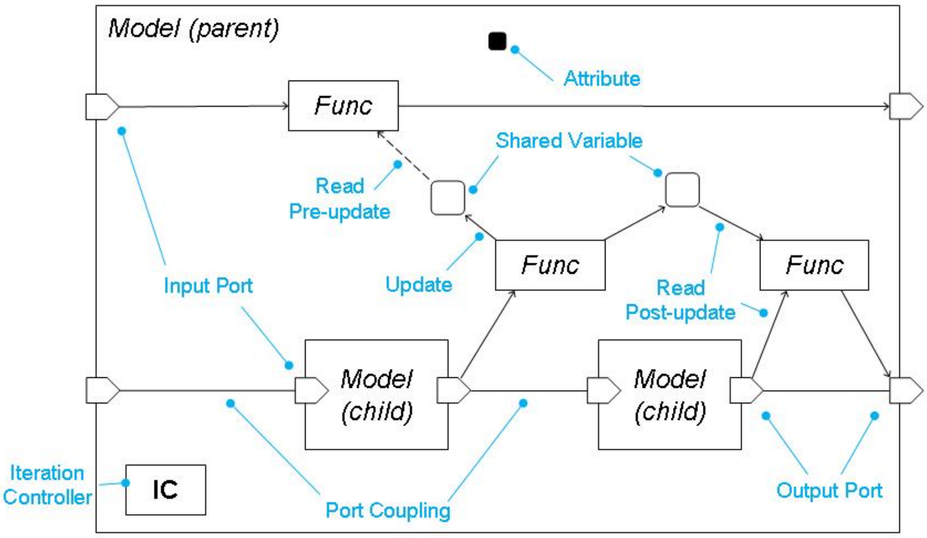
Proposal

- Use a modified concept of a SysML Internal Block Diagram that support definitions of mathematical algorithms to represent continuous system behaviour (including generation of discrete events).

Model Symbology

Elements	Relationships
Model	Update
Child Model Interface	Read Post-update
IC — Iteration Controller	Read Pre-update
Function	Port Coupling
Input Port (Variable)	
Output Port (Variable)	
Shared Variable	
Attribute (Variable)	

Model Diagrams



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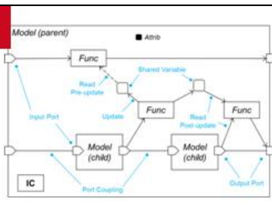
Specification



- Models are defined by:
  - An interface, which consists of any number of Input and/or Output Ports.
  - An internal definition consisting of any number of Functions, Shared Variables, Attributes, or interfaces of Child Models.
  - Relationships between Functions and Variables (including Ports of child Models).
  - Zero or One Iteration Controller.

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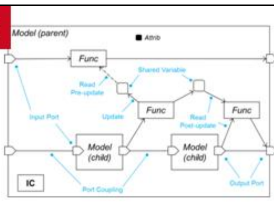
Specification



- Functions
  - Must have a means of indicating to Iteration Controllers which MoC they are dependent upon, if any.
- Variables
  - Attributes are constant Variables that are only updated when the owning model is instantiated.
    - All Functions have Read pre-update access to Attributes
  - Can support ‘tags’ that will have specific meaning to certain MoC.

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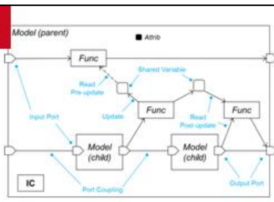
Specification



- Update Relationship
  - The source end must connect to a Function. The target end must connect to either a Shared Variable, parent Model’s Output Port, or a child Model’s Input Port.
- Read post-update Relationship
  - The target end must connect to a Function. The source end must connect to either a Shared Variable or Port.
- Read pre-update Relationship
  - The target end must connect to a Function. The source end must connect to either a Shared Variable or Port.

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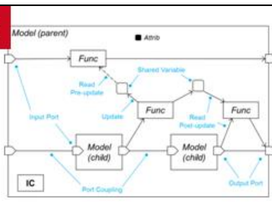
Specification



- Coupling Relationship
  - Connects either:
    - An Input Port of the parent Model to an Input Port of a child Model;
    - An Input Port of the parent Model to an Output Port of the parent Model;
    - An Output Port of a child Model to an Input Port of a child Model;
    - An Output Port of a child Model to an Output Port of the parent Model.
  - Copies updated content of the source Port (parent Model's input or child Model's output) to the target Port.

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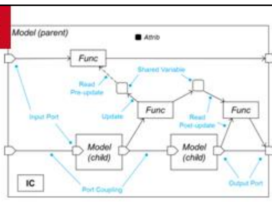
Specification


Model (parent)
Attrib
Func
Shared Variable
Read
Pre-update
Input Port
Update
Func
Read
Post-update
Func
Model
(child)
Model
(child)
IC
Port Coupling
Output Port

- Iteration Controller
  - Embodies a specific Model of Computation.
  - Coordinates the execution of a set of Functions within the Model in which it is declared according to relationships between Functions and Variables and specific MoC rules.
    - Selection of the set of Functions depends on the specific IC.
    - A Function dependent on a MoC cannot be executed under another MoC.
  - An IC must itself be expressed as one or more Functions that can be executed by a parent IC.

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Variable step Discrete Time MoC

- Definition: For time t in each iteration i conforming to the Discrete Time model of computation.

$$t_{i+1} - t_i > 0$$

- Functions may 'request' a time value for a future DT iteration.
  - The DT IC will determine the time of the next DT iteration as the minimum all requests.
- Discrete Event simulations can be formulated in this DT MoC.

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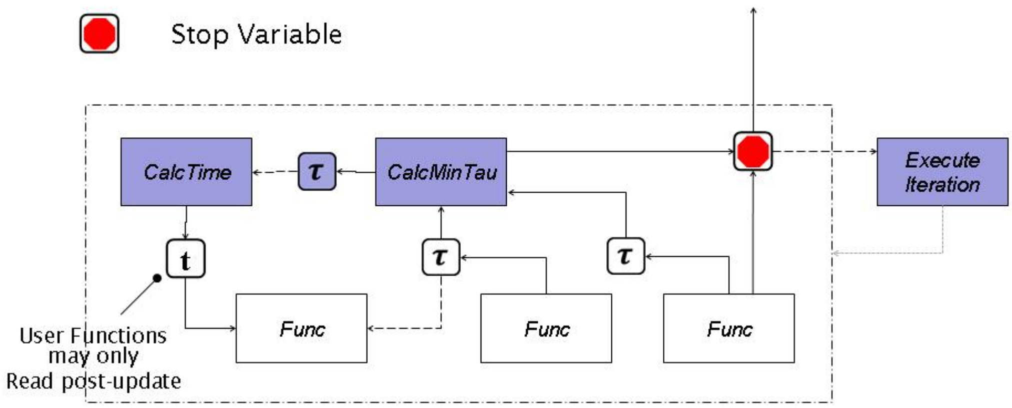
Elements supporting DT MoC

$\boxed{t}$ Time Variable

$\boxed{\tau}$ Time Request Variable

Stop Variable



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ODE Solving MoC

- Definition: A coordinated solving of simultaneous ODEs according to the users choice of integration algorithm as applied to a selected integrators.
- Works within the DT MoC
  - Non-causal (eg. Runge-Kutta) algorithms result in multiple 'intermediate' iterations of a Functions that calculate derivatives. These iterations are ODE MoC specific.

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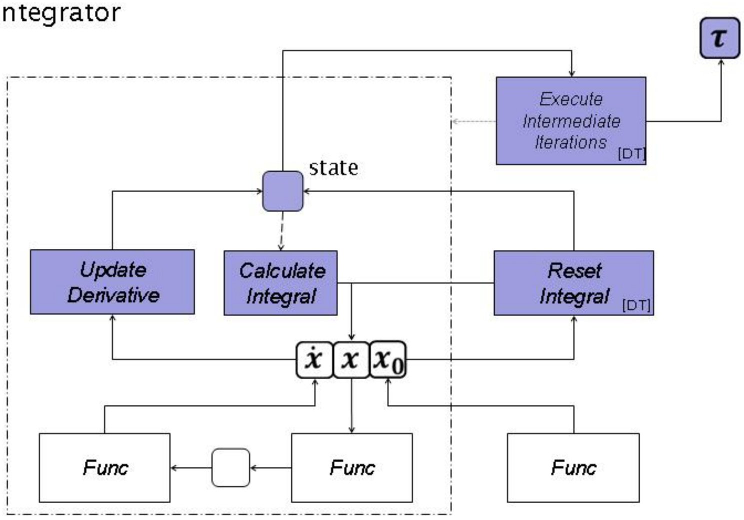
Elements supporting ODE Solver MoC

$\boxed{\dot{x}}\boxed{x}\boxed{x_0}$ Integrator



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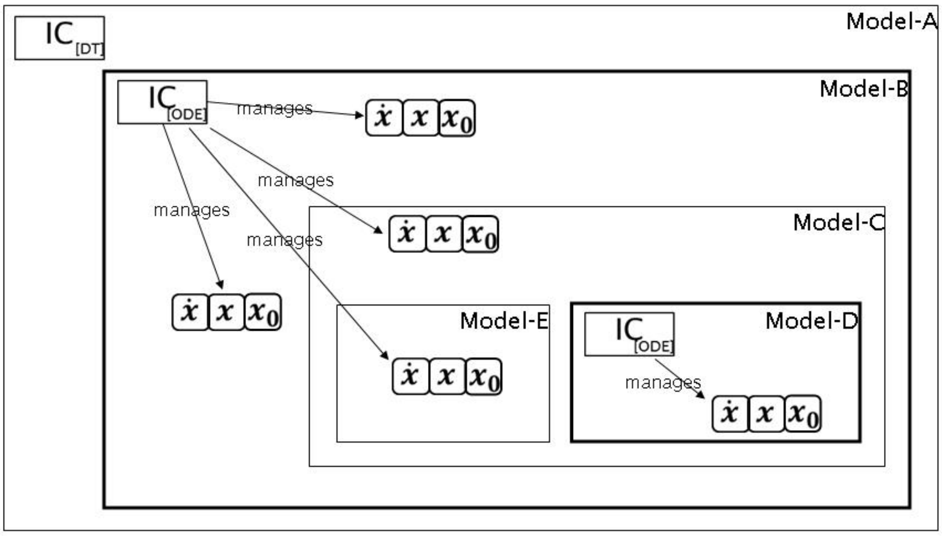
Selection of ODE Sub-network of Functions



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Drawing the line between in-built MoC and User defined Model constructs

- There are many subtle algorithmic design patterns that if not built into an MoC must (if needed) be implemented by the modeller. Most are not particularly universal in application.
- Specific Function triggering (over and above MoC dependencies):
  - Input Variable update;
  - Time = Tau (in DT MoC).
- Function or Model enabling/disabling.
- Automatic clearing of data from variables between iterations.

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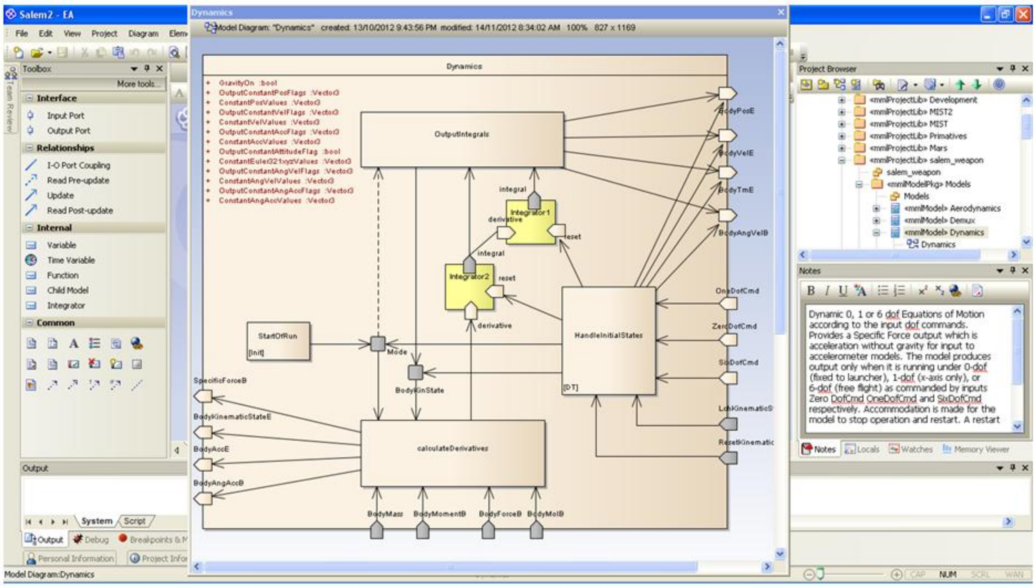
Walking the walk



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FIN

Questions

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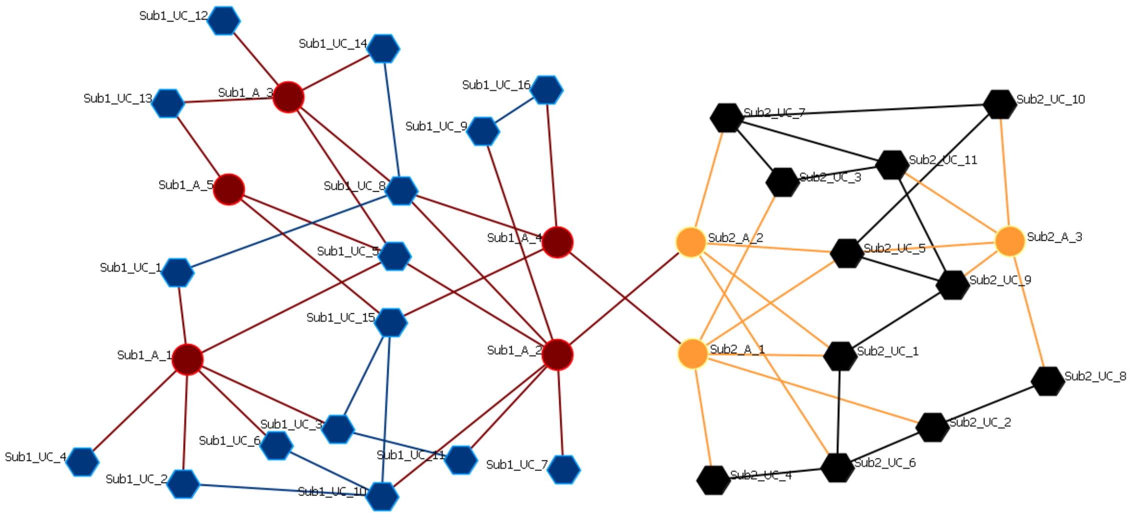
17. Towards the Use of Network Analysis Method In Analysing Node Properties In A System Model

Li Jiang and Hossein Seif Zadeh
Joint Operation Division, DSTO

Abstract

Model-based system engineering methodologies advocate using system models as the main vehicle in system engineering processes[12]. In this methodology, a system model represents the relationships and interaction between the entities being modelled. **Figure 2** depicts an example of such abstraction of the interaction within and between two subsystems.



(a) The first component network **(b) The second component network**

Legend: Filled circles represent actors or agents
Filled diamonds represents use cases or components
Different colours are used to distinguish actors (agents) or use cases (components) in each subsystem.

Figure 2 A sample component network of two subsystems

As a result of the difficulty in understanding complex relationships within comprehensive systems models, there is a need for a systematic approach in assessing properties of such models[13].

---

[12] Estefan, J. (2008). *Survey of model-based systems engineering (MBSE) methodologies*. Pasadena, California. USA, Jet Propulsion Laboratory, California Institute of Technology

[13] Brooks, R. J. and A. M. Tobias (1996). *Choosing the Best Model: Level of Detail, Complexity, & Model Performance*, Mathematical and Computer Modelling, Volume 24, Number 4, August 1996 , pp1-14 testing

Lacking evaluation mechanism for system models presents three major problems:

(1) difficulty in understanding fundamental properties of the model which are often attributed as a major reason for failure of the system;

(2) lack of a systematic and efficient mechanism in ensuring consistency of the model through all stages of process, system, and product development[14]; and

(3) difficulty in understanding which components perform critical functions, and which components serve as a bridge between sub-systems.

This paper presents a two-step approach in assessing properties and consistency of the model. The definitions of the properties and consistency are briefly discussed below:

- Properties are defined based on a set of network science measures[15]. To use the network science measures, the relationships between entities in the system model are represented as an entity network (see Figure 1 for a simple example). The network measures can be computed and the results of the computation can be explained meaningfully within the system engineering discipline.
- Consistency refers to the congruent between entities or artefacts developed in the system development process. These measures can be quantitative or qualitative.

Jiang et al[16] have shown that, in the context of software development, analysing properties of a model provides meaningful feedback for the purpose of design and system verification processes.

The proposed approach provides a practical mechanism for analysing properties of the system. The major contribution of this work is two folds:

(1) properties of system models can be used at both network and node level, containing critical information on the overall entity network, and

(2) consistency-assessment measures provide a mechanism to verify consistency of the system model.

The implication and significance of using properties of nodes within the context of system engineering are also discussed.

[14] Van Der Straeten, R., T. Mens, et al. (2003). *Using description logic to maintain consistency between UML models*. «UML» 2003-The Unified Modeling Language. Modeling Languages and Applications: 326-340.
[15] Wasserman, S. and K. Faust (1995). *Social Network Analysis: Methods and Applications*. Cambridge, University of Cambridge Press
[16] Jiang, L., K. M. Carley, et al. (2012). *The Impact of Component Interconnections On Software Quality: A Network Analysis Approach*. The 2012 IEEE International Conference on Systems, Man, and Cybernetics (IEEE SMC 2012)

Presenter Biographies

Dr. Li Jiang obtained his PhD in Nov. 2005. He has more than 50 publications with more than 30 published in the reputed international journals and conferences. He won many awards including Canadian PhD scholarship in 2002, Canadian visiting fellowship from Natural Sciences and Engineering Research Council of Canada in 2006. After completion of his PhD., Dr. Li Jiang started to work as a lecturer in the Department of Computer Science at the University of New Brunswick, Canada, in 2005 and a lecturer in the School of Computer Science at the University of Adelaide, Australia since Nov. 2006. Dr. Jiang started to work at DSTO in Canberra from August, 2012. Dr. Jiang has been a visiting scientist at the University of Carnegie Mellon University, University of Calgary, and University of Nottingham in 2011, 2001 and 1995 respectively.

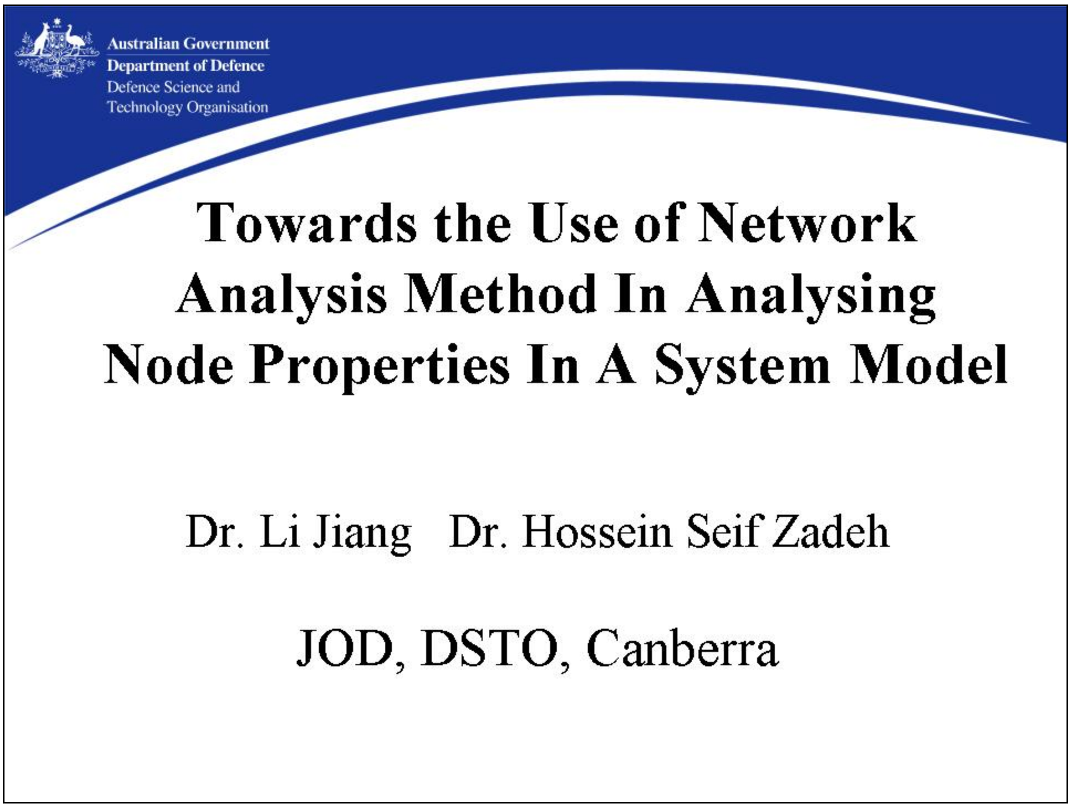
Besides having academic experience in Canada and Australia, Dr. Jiang also has more than 7 years working experiences in software industry both in China and Canada as programmer, analyst, architect, and project manager.

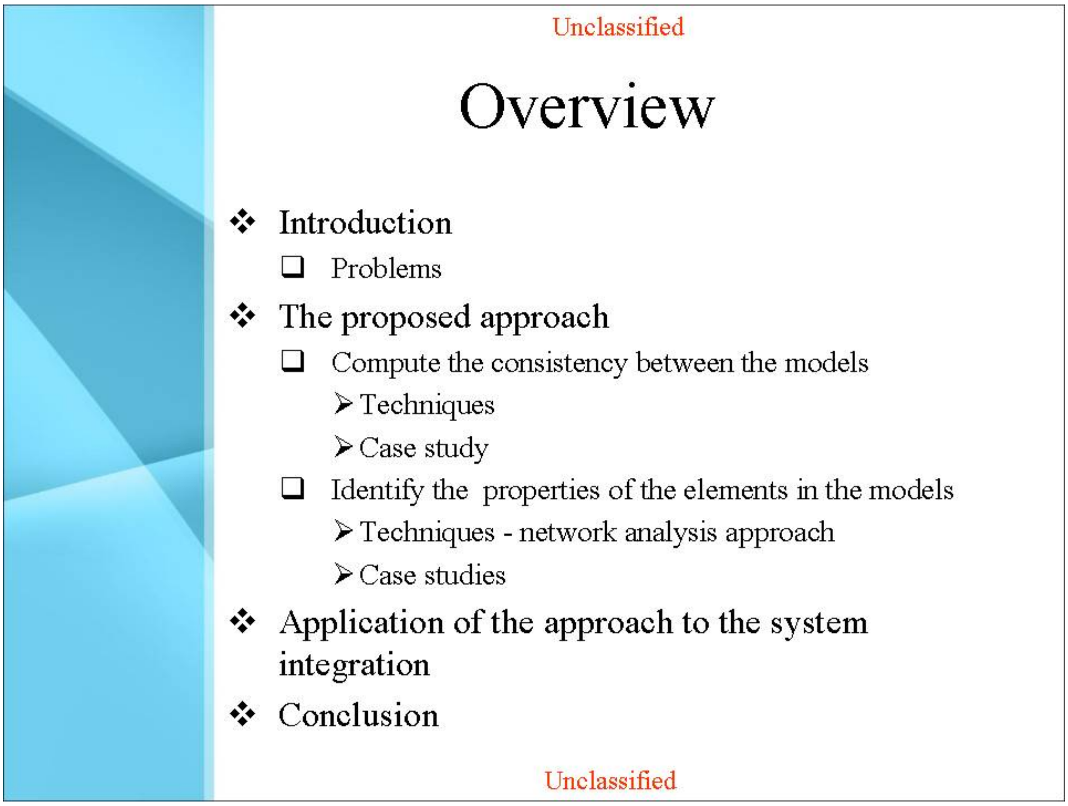
Hossein Seif Zadeh's career includes positions as research scientist, senior IT manager, senior project manager, management consulting, system analyst, and educator. Dr. Seif Zadeh's experience combines disciplines of mechanical and aerospace engineering in the one hand and management and information systems in the other. He has researched and published in fields as diverse as manoeuvre control of satellites to the innovative applications of information systems in healthcare.

After a management experience looking after a large-scale IT department with 15,000+ clients, and a successful academic career, Hossein now holds the position of Science Team Leader at DSTO Fairbairn. His research, linking the diverse fields of engineering, management, and IT has attracted over $1,000,000 in grants, awards, scholarships and contracts, from organizations such as the Australian Research Council and Department of Defence. In 2004, Hossein was a visiting scholar at Linkoping University, Sweden, and in 2009/2010, was a Distinguished Visiting Scholar at IBM Almaden Research Labs, San Jose, USA.

Hossein is a continuing reviewer of multiple international journals and conferences, was associate editor of IT Services track in ICIS 2010 and is mini-track chair of AmCIS 2011, and has been a session organizer and reviewer of IEEE Aerospace conference since 2002. In 2010, Hossein was a recipient of the prestigious and internationally-recognized IBM Faculty Award, and in 2012 was selected as a Fellow of Schoeller Research Center in Germany.

Presentation





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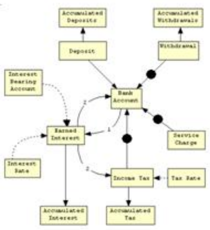
Introduction

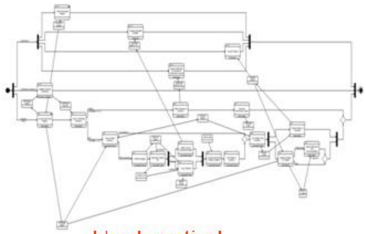
- Introduction
- Compute the consistency
- Identify the properties
- Application to the system integration
- Conclusion

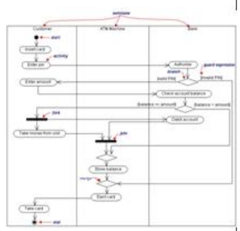
Model-based system engineering (MBSE)

❖ MBSE is the formalized application of modelling to support system requirements, design, analysis, verification and validation activities in the system engineering life cycle.

- ❑ Requirements Models – Requirement Diagram
- ❑ Design Models - Package Diagram, Sequence Diagram, Activity Diagram, State Machine Diagram, etc.







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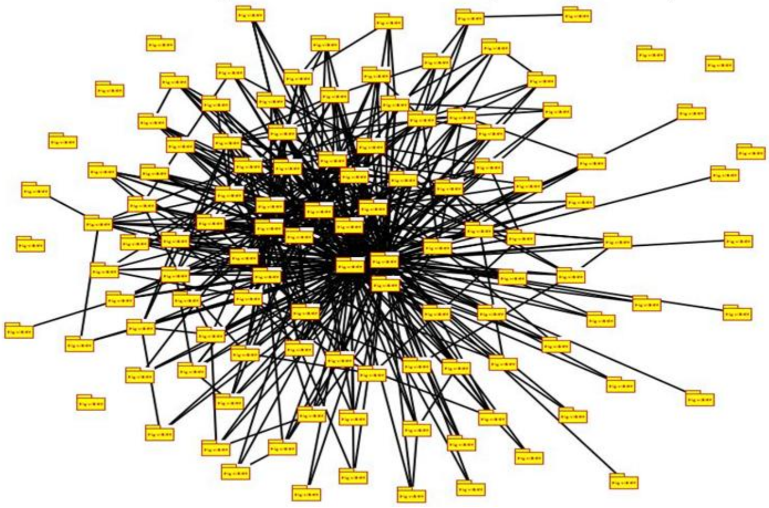
Introduction (Cont'd)

- Introduction
- Compute the consistency
- Identify the properties
- Application to the system integration
- Conclusion

❖ Problems

- ❑ Hard to ensure the consistency between the designs and evolutions of design.
- ❑ Hard to identify the critical elements (nodes) in the system



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Introduction

Compute the consistency

Identify the properties

Application to the system integration

Conclusion

Introduction (Cont'd)

- How to verify and evaluate the system models remains challenges in both industry and academia
  - Status quo in industry practices
  - Research – major focus on mathematical approaches
    - model-checking and automated theorem proving
    - using description logic to maintain consistency
- Lacking evaluation and/or verification mechanism for system models presents three major problems
  1) lack of a systematic and efficient mechanism in ensuring consistency of the model
  2) difficulty in understanding which components perform critical functions
  3) difficulty in understanding fundamental properties of the model

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Introduction

The Proposed Approach

Compute the consistency

Identify the properties

Application to the system integration

Conclusion

The Proposed Approach

- An approach is proposed for verification and evaluation of the models.

  The approach include two parts:

  (1) Define a set of measures to compute the consistency between the models.

  (2) Using several network measures to identify the properties of the elements in the model.
    - Compute the complexity of the model
    - Compute the properties of the elements in the model.

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Introduction

The Proposed Approach

Compute the consistency

Identify the properties

Application to the system integration

Conclusion

The Proposed Approach (Cont'd)

- Assumption with the approach:
  - The system design following the system engineering process and SysML (or UML) are used in the design.
  - The relationships between the requirements, objects, components or package of the system in the system models are well-established.
  - Targeting on the project covering the entire system development lifecycle.
- The applicability of the approach to the system integration is briefly discussed at the end of the presentation.

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Introduction

The Proposed Approach

Compute the consistency

Identify the properties

Application to the system integration

Conclusion

Part 1: Compute The Consistency Between The Models

Step 1: Define a set of measures

- The measures are divided into following classes
  - Quantity metrics
    - counts of the design entities and relationships.
  - Complexity metrics
    - measure the relations between design entities and the structure of the proposed system architecture.
  - Quality metrics
    - measure the relationship between the desired and the actual characteristics of the architecture.

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Introduction

The Proposed Approach

Compute the consistency

Identify the properties

Application to the system integration

Conclusion

Part 1: Compute The Consistency Between The Models (Cont'd)

- Examples of the proposed quantity metrics for evaluation of the models
  - Number of Diagrams
    - Package Diagrams, Use Case Diagrams, Sequence Diagrams, State Diagrams, Activity Diagrams, Requirements Diagram, Class Diagram
  - Number of entities
    - Requirements, Use Cases, Actors, Activities, Package
  - Number of design relationship type
    - Links between entities, Interactions, Activity Flows, State Transitions.

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Introduction

The Proposed Approach

Compute the consistency

Identify the properties

Application to the system integration

Conclusion

Part 1: Compute The Consistency Between The Models (Cont'd)

- Examples of the proposed complexity metrics

$$OverallDesignComplexity = 1 - \left[\frac{\mathrm{No\_DesignEntities}}{\mathrm{No\_Relationships} + \mathrm{No\_Actors}} \right]$$

$$UseCase\_Complexity = 1 - \left[\frac{\mathrm{No\_UseCase}}{\mathrm{No\_Relationships} + \mathrm{No\_Actors}} \right]$$

$$Object\_Interation\_Complexity = 1 - \left[\frac{\frac{\mathrm{No\_of\_Object}}{\mathrm{No\_of\_Object\_Interaction}} + \frac{\mathrm{No\_of\_Classes}}{\mathrm{No\_of\_Class\_Association}}}{2} \right]$$

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Introduction

The Proposed Approach

Compute the consistency

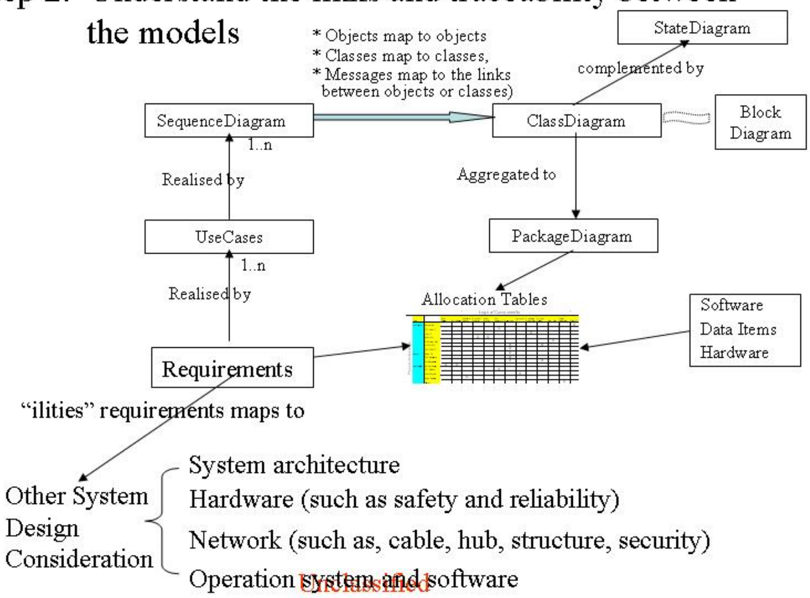
Identify the properties

Application to the system integration

Conclusion

Part 1: Compute The Consistency Between The Models (Cont'd)

Step 2: Understand the links and traceability between the models



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Part 1: Compute The Consistency Between The Models (Cont'd)

Step 3: Define a set of consistency measures

$$DegreeOfConsistency_{req\_usecase} = \frac{No\_RequiremetnsRealisedByUseCases}{No\_Requirements}$$

$$DegreeOfConsistency_{usecase\_SeqD} = \frac{No\_UseCasesModelledBySequenceDiagram}{No\_UseCases}$$

$$DegreeOfConsistency_{SeqD\_ClassDiagram} = \frac{No\_ClassesInClassDiagram + No\_ObjectsInObjectDiagram}{No\_ClassesInSequenceDiagram + No\_ObjectsInSequenceDiagram}$$

$$DegreeOfConsistency_{classes\_methods} = 1 - \frac{No\_UndefinedMethodsReferences + No\_UnderfinedParameterReferences}{No\_DefinedMethods + No\_DefinedParameters}$$

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Part 1: Compute The Consistency Between The Models (Cont'd)

Case Study 1: Compute the consistency between the models

- Data Sources: Student Group's Design Documents:
- Information about the students:
  - Year 3 students from computer science, math and other engineering program.
  - Students are involved in Group Project with 5 to 6 group members.
  - Intensive one term-long project supervised by lecturers
  - The project is about developing a robot that can detect mines in the "battle field"
  - Students are guided through the entire engineering process from requirements gathering to the final deliverables
  - Students uses various engineering process models
  - SRS, SDD, SPMP are compulsory deliverables and presented during the processes of the project

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Part 1: Compute The Consistency Between The Models (Cont'd)

Case Study 1: Compute the consistency between the models

- Data Sources: Student Group's Design Documents:
- Information about the students:
- Results

	Group 1 (2010)	Group 15 (2010)	Group 5 (2011)	Group 4 (2011)
DegreeOfConsistency (Requirements and Usecases)	0.72	0.83	0.88	0.69
DegreeOfConsistency (Usecases and SequenceDiagram)	0.60	0.58	0.83	0.80
DegreeOfConsistency (SequenceDiagram and ClassDigram)	0.93	0.57	0.79	0.49
Overall Consistency	0.40	0.27	0.58	0.27
Average	0.78	0.69	0.84	0.67

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Part 2: Identify the properties of the elements in the models

- Introduction
- The Proposed Approach
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- Identify the properties
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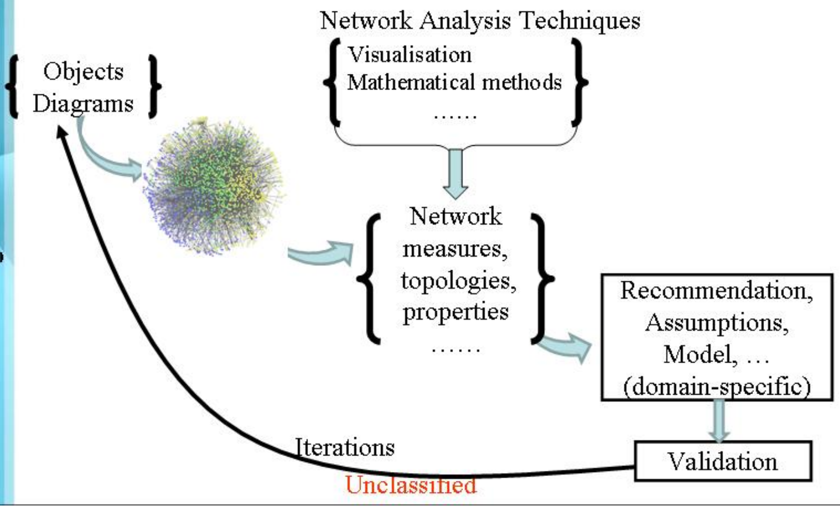
❖ **Using network analysis approach**



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Part 2: Identify the properties of the elements in the models (Cont'd)

- Introduction
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- Compute the consistency
- Identify the properties
- Application to the system integration
- Conclusion

❖ Examples of network measures used
- ❑ Network level
  - ➢ Network Size, Link count, Density, Isolate count (Component count), Clustering coefficient
- ❑ Node level
  - ➢ Degree centrality, Betweenness centrality, Eigenvector centrality, Closeness centrality

❖ Network analysis techniques used
- ❑ Visualisation
- ❑ Computation analysis
- ❑ Statistical analysis

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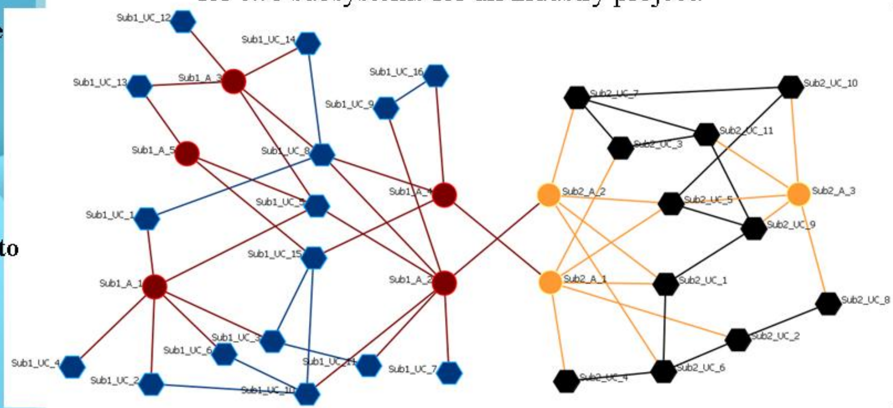
Part 2: Identify the properties of the elements in the models (Cont'd)

- Case study 2
  - Analyse the critical nodes in the two use case diagrams for two subsystems for an industry project.



Note: Filled-circles represent actors or agents and filled-diamonds represents use cases

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Introduction

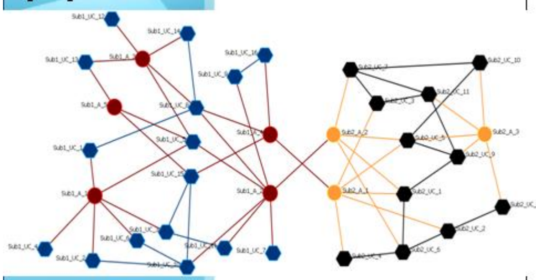
The Proposed Approach

Compute the consistency

Identify the properties

Part 2: Identify the properties of the elements in the model (Cont'd)

- Case study 2
  - Analyse the critical nodes in the two use case diagrams for two subsystems for an industry project.
  - Compute the measures
  - Analysis the results



Rank	Total degree centrality	Betweenness centrality	Closeness centrality	Eigenvector centrality
1	Sub1_A_2	Sub2_A_1	Sub1_A_2	Sub2_UC_5
2	Sub1_A_1	Sub2_A_2	Sub1_A_4	Sub2_A_2
3	Sub2_A_1	Sub2_UC_5	Sub1_A_1	Sub2_A_1
4	Sub1_A_3	Sub1_UC_8	Sub2_A_1	Sub2_A_3
5	Sub1_UC_8	Sub2_UC_3	Sub2_A_2	Sub2_UC_9
6	Sub2_A_2	Sub2_UC_7	Sub1_A_3	Sub2_UC_1

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Part 2: Identify the properties of the elements in the model (Cont'd)

- The empirical verification of the model:
  - Project actual results obtained from programmers and testing engineers
    - Following use cases took more time to implement than other nodes:

      Sub1_A_2, Sub1_A_1, Sub2_A_1 , Sub1_A_3
    - Following use cases took more time to implement than other nodes and more test cases were required and implemented in the testing process than other nodes:

      Sub2_UC_5 , Sub1_UC_8, Sub2_UC_3, Sub2_UC_7

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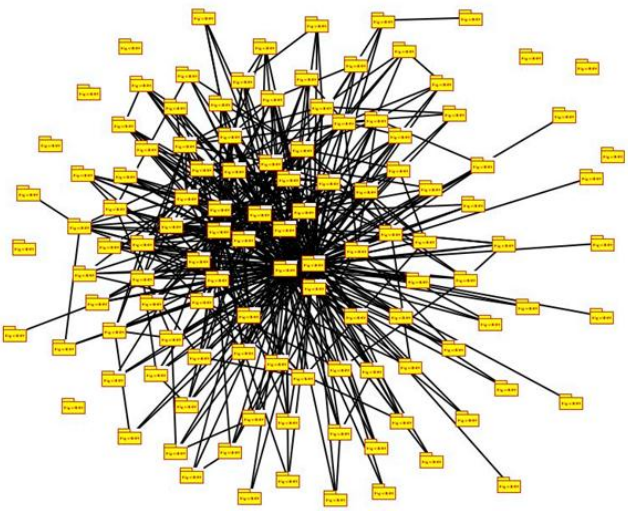
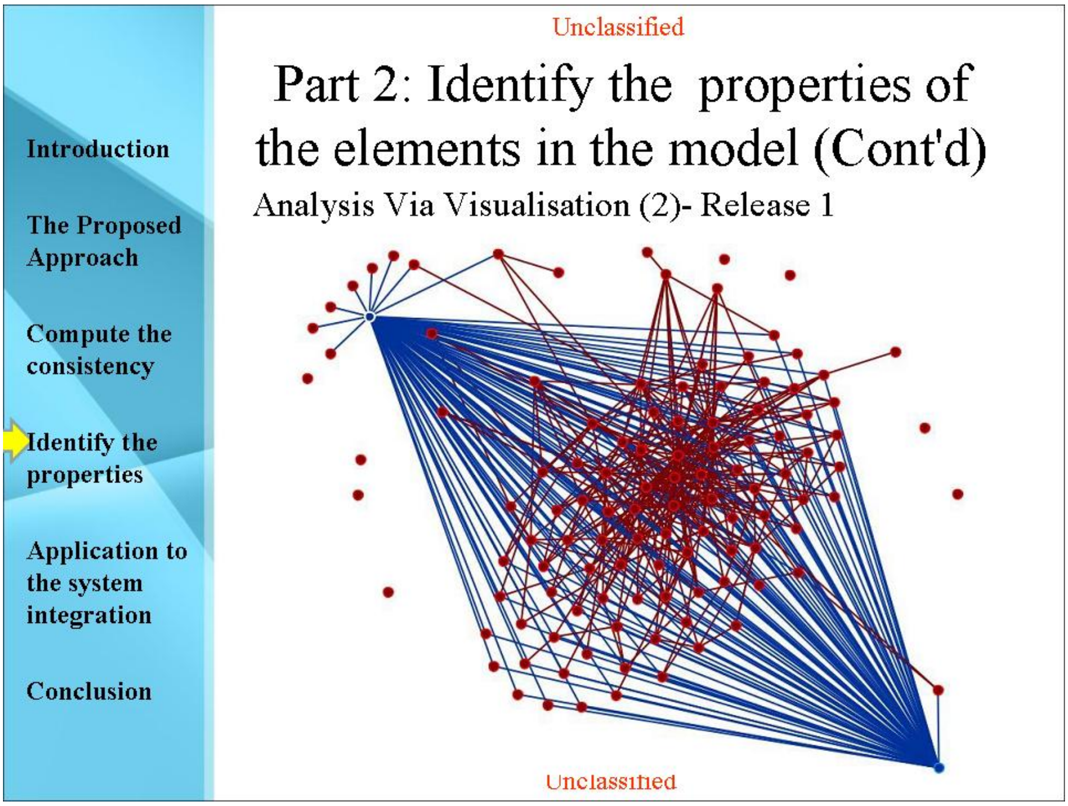
Part 2: Identify the properties of the elements in the model (Cont'd)

- Case study 3
  - Visualisation of the system architecture

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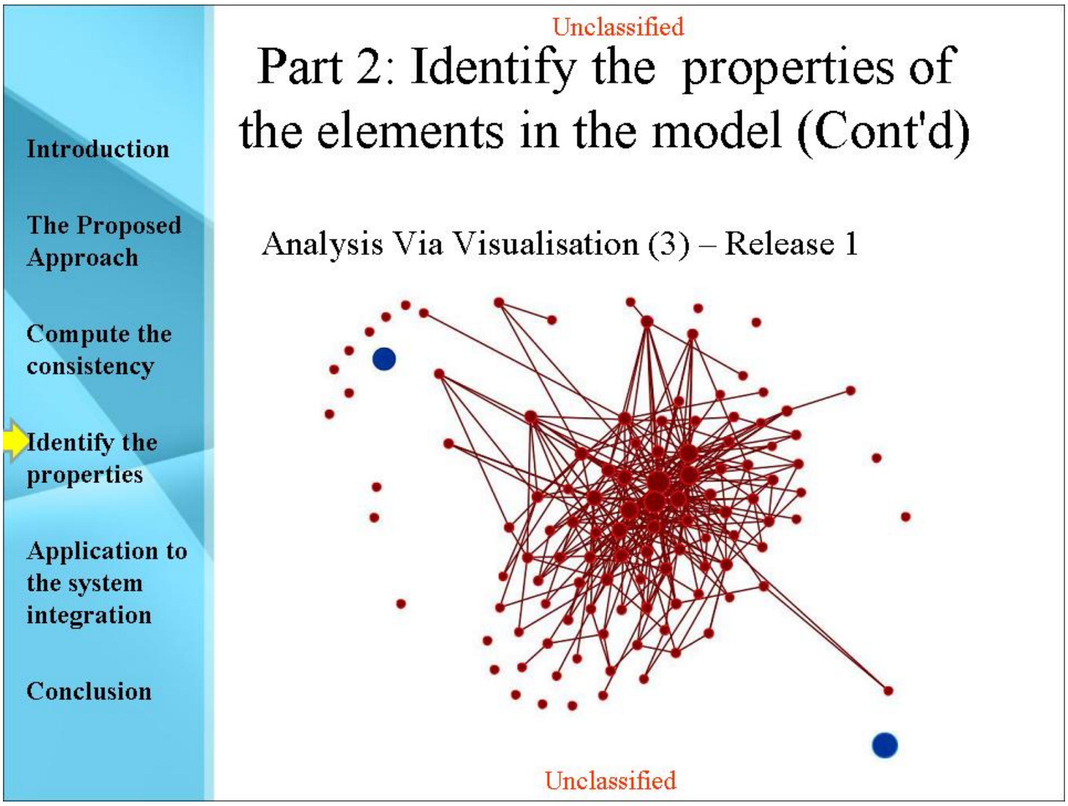
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Part 2: Identify the properties of the elements in the model (Cont'd)
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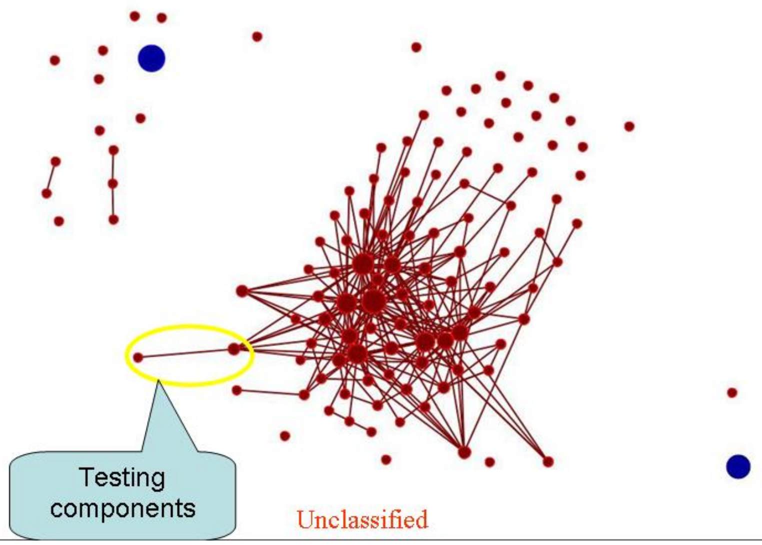
Part 2: Identify the properties of the elements in the model (Cont'd)

Analysis Via Visualisation (4) - Release 2



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Conclusion

Application of the approach to the system integration

- The major problems involved in system Integration
  - Difficult in modification and maintenance
    - Difficulty in understanding the existing system and interfaces
  - Not coherent and not unifying data structure
  - Many different application and systems to supports
    - incompatible system and/or system interfaces
  - Aging of the systems
  - Social issues
  - ……

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The Proposed Approach

Compute the consistency

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Application to the system integration

Conclusion

Application of the approach to the system integration (Cont'd)

- The proposed approach is still applicable
  - For integrating the systems with well-defined system models
    - The approach enforces the consistency checking principles
    - Network analysis approach can provide good information about which components (nodes) are vulnerable and with higher complex (higher values of centrality and/or centrality betweens)
  - For integrating a new system to an old system without the well-developed models
    - If the old system can be reverse-engineered
      - some models can be obtained and can be used for analysis as discussed before
    - If it can not be reverse-engineered
      - the old system has to be understood, and architecture level node connections will need to be developed.

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Conclusion

Conclusion

- **Conclusion**:
  - MBSE provides a practical approach to develop complex systems
  - Models produced in the system engineering processes have to be evaluated or assessed to ensure that the requirements are fully implemented, and models are consistent throughout the entire engineering process.
    - The proposed approach is the first step toward addressing the issue
    - More research is required to address other burning issues
  - In order to have better understanding of the system, models have to be studied from holistic level
    - Networks science provides good tools for studying the holistic view of the system, the interconnections, and their changes/evolutions

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18. Technical Risk Analysis – Exploiting the Power of MBSE

Despina Tramoundanis[1], Wayne Power[1] and Daniel Spencer[2]
[1]Weapons Systems Division, DSTO and [2]Aerospace Concepts

Abstract

In his 2003 review into Defence procurement, Kinnaird recommended that for new acquisitions Defence undertake a '*comprehensive analysis of technology, cost and schedule risks*' and that '*Government needs to be assured that adequate scrutiny is undertaken ….by DSTO on technology feasibility, maturity and overall technical risk*'. As a result, DSTO performs Technical Risk Assessments (TRA) to inform major acquisition decisions during the Requirements phase of the Capability Development process.

Instructions for preparing the TRA are found in the Technical Risk Assessment Handbook (TRAH)[17]. These instructions provide useful guidance on the nature of technology and technical risks and means for risk discovery and assessment.

The current TRA development practice has several shortcomings, including:

- Existing templates do not necessarily fit every type of acquisition project.
- At the early stages of capability definition, before a materiel solution has been selected, system decomposition is not always possible.
- The level of discipline and rigour applied to risk analysis is variable depending on the skills of individuals.
- System integration risk does not receive adequate coverage.
- The TRA is a stand-alone document meaning that the risk analysis is not necessarily integrated with the capability definition.
- It is not easy to see how risks in one part of the system impact risks in other parts of the system that may be directly or indirectly coupled.

To address several of these shortcomings, this paper introduces the concept of Functional Risk Analysis (FRA) conducted within a Model Based Systems Engineering (MBSE) environment. FRA is a rigorous technique used to explore potential effects of functional failures or degradation that result from insufficient technical readiness, both within and between parts of a system and across system interfaces. (FRA is analogous to Functional Hazard Analysis, a technique applied in the aerospace domain.) The underlying method of FRA uses an Enhanced Functional Flow Block Diagram (EFFBD) representation of the system functionality and follows the following procedure:

1. Perform the following steps on each function in turn:
   a. Define the purpose and behaviour of the function.
   b. Consider the technologies inherent in the function and the potential failure modes that may result based on an understanding of the technology readiness,

[17] DSTO, Technical Risk Assessment Handbook, Version 1.1, 2010

e.g. 'complete loss of function', 'degraded performance', 'incorrect operation (e.g. high, low, fast, slow etc …)'.
    c. Represent functional failure modes within MBSE model.
2. Simulate or interrogate the functional model to assess the potential impact of functional failures on downstream functions and guide detailed system analysis.
3. Record in the MBSE model the identified risks (i.e. the potential effect in terms of severity and probability of occurrence).

Once the physical system has been designed or selected, the FRA procedure can be repeated using the system architecture to assess and explore the effects of component failures or degradation that result from insufficient system readiness. The results of the FRA are recorded in the MBSE model from which the TRA report is auto-generated via the running of scripts. This paper will use a generic weapon system example to illustrate the FRA technique.

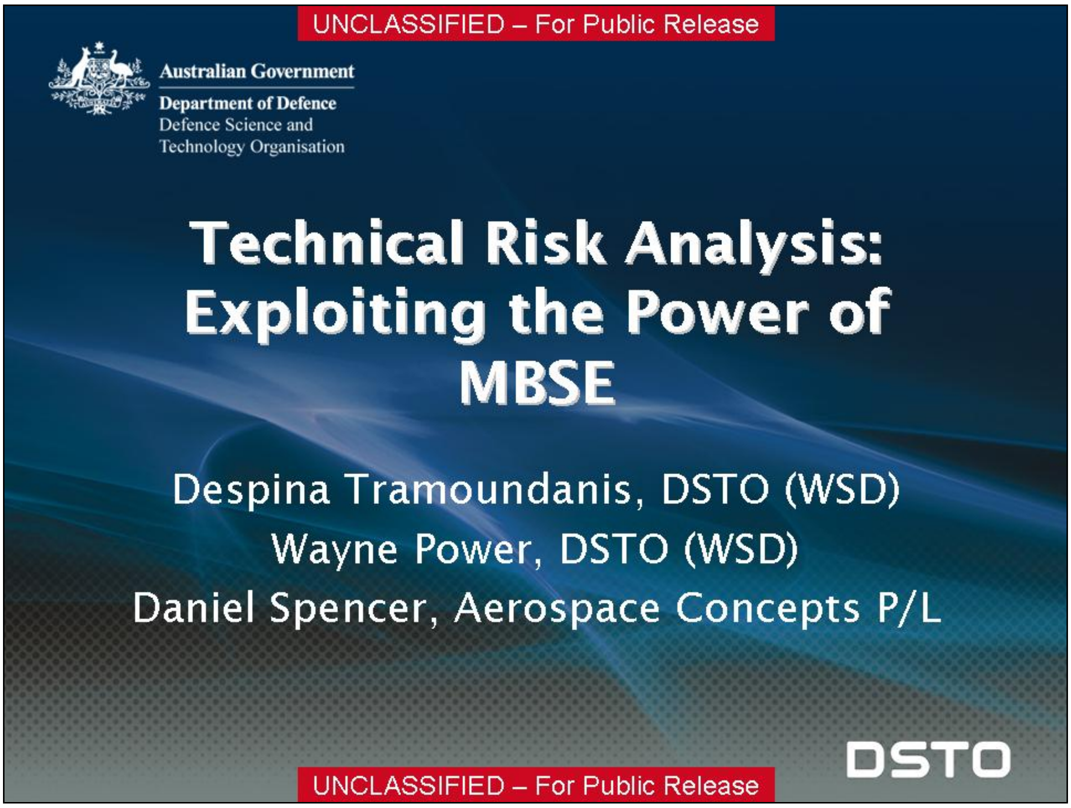
Presenter Biography

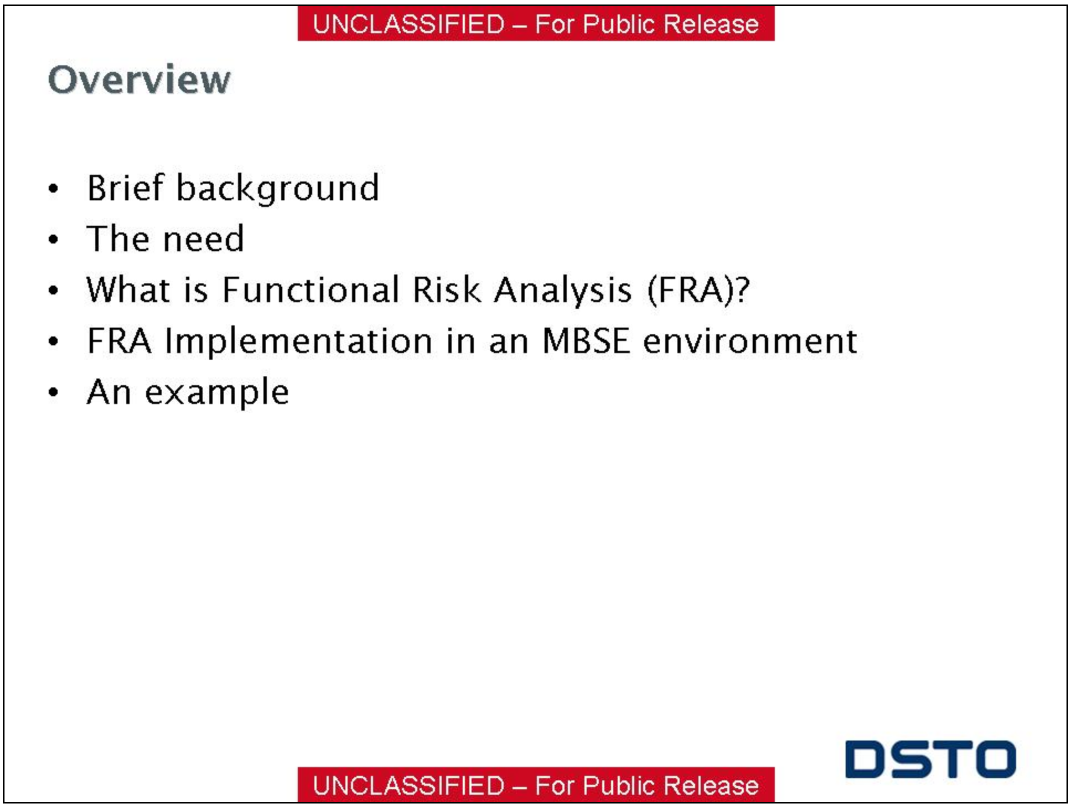
Despina Tramoundanis was a Royal Australian Air Force Armaments Engineer for 20 years before joining DSTO's Weapons Systems Division. She is currently the S&T advisor for a Ground-Based Air and Missile Defence project. Her current research interests include development of the Whole-of-System Analytical Framework, a Model-Based Capability Engineering methodology for the provision of cross-Defence modeling, simulation, analysis and Capability Development activities. She holds a Bachelor of Engineering (Chemical) from Monash University, an MSc in Explosives Engineering from Cranfield University (UK), a Master of Defence Studies from UNSW and a Master of Defence Operations Research from UNSW.

Wayne Power graduated with honours from the Queensland University of Technology (QUT) with a Bachelor of Engineering (Aerospace Avionics), minor in Systems Engineering. He has spent the last six years working in Weapons Capability Analysis within DSTO's Weapons Systems Division (WSD). His work in WSD has included weapon system integration modelling and analysis, but the major focus of his work has revolved around researching and developing the Whole-of-System Analytical Framework (WSAF). The WSAF employs a Model-Based Systems Engineering approach for the provision of cross-Defence modelling, simulation, analysis and Capability Development activities.

Daniel Spencer works as a systems engineer for Aerospace Concepts Pty Ltd. He has over a decade of experience in design and development of systems solutions across a broad range of industries, both in Australia and the United Kingdom. Dan holds a Bachelor of Engineering in Information Technology and Telecommunications from the University of Adelaide. He has been working with Australian Defence clients developing and refining tools and methods for a repeatable and comprehensive MBSE method, while using this approach for real-world capability definition and development projects.

Presentation





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Background

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Kinnaird (2003):

For new acquisition Defence should undertake a *'**comprehensive analysis of technology,** cost and schedule **risks**'*

*'Government needs to be assured that adequate **scrutiny** is undertaken … **by DSTO on** technology feasibility, maturity and overall **technical risk**'.*

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Technical Risk Assessment

- Pre-1st Pass: TRI
- 1st-Pass & 2nd Pass: TRA
- Technical Risk Assessment Handbook (TRAH)
- TRA templates
- Based on
  - Technical Readiness Levels (TRLs)
  - Risk assessment matrix

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The Need

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Shortcomings

- TRA templates do not fit every type of acquisition
- Work only with materiel solutions
- Quality depends on the skills of individuals
- Inadequate analysis of:
  - System integration risk
  - Risk coupling
- TRA is a stand-alone document

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The Need

A rigorous technique to explore the potential effects of functional failures and performance degradation that result from insufficient technical readiness, both within and between parts of a system and across system interfaces

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Functional Risk Analysis (FRA)
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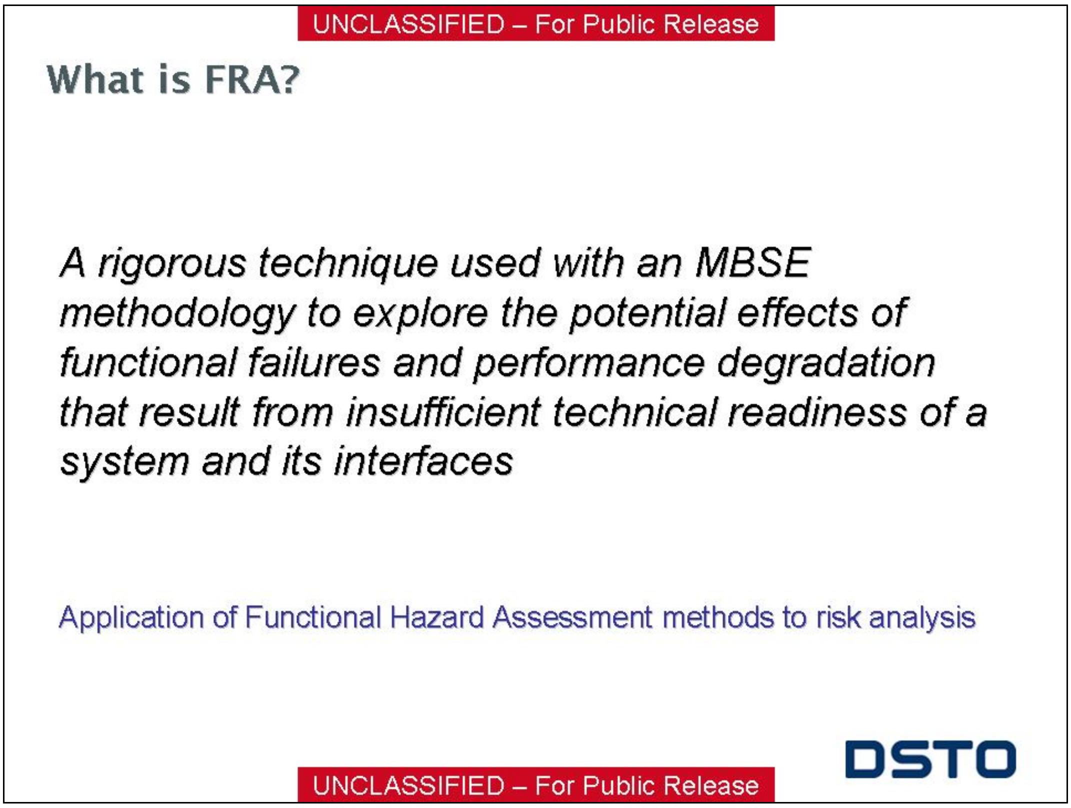
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What is FRA?
A rigorous technique used with an MBSE methodology to explore the potential effects of functional failures and performance degradation that result from insufficient technical readiness of a system and its interfaces
Application of Functional Hazard Assessment methods to risk analysis
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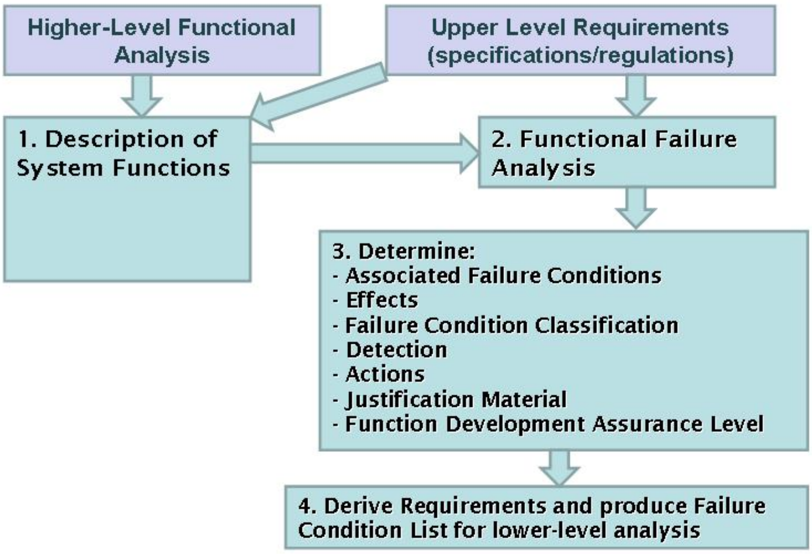
Functional Hazard Assessment

(modified from SAE ARP4761)



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FRA Procedure Overview

- Commence with a functional decomposition of the capability system and include the system interfaces.
- Define the purpose and behaviour of each system function.
- Consider potential failure modes of each function eg loss or degradation of function
- Determine the effect of each failure on system function and operational / mission outcomes
- Identify, analyse and record the risks (impact and likelihood)

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Applying FRA as part of an MBSE methodology
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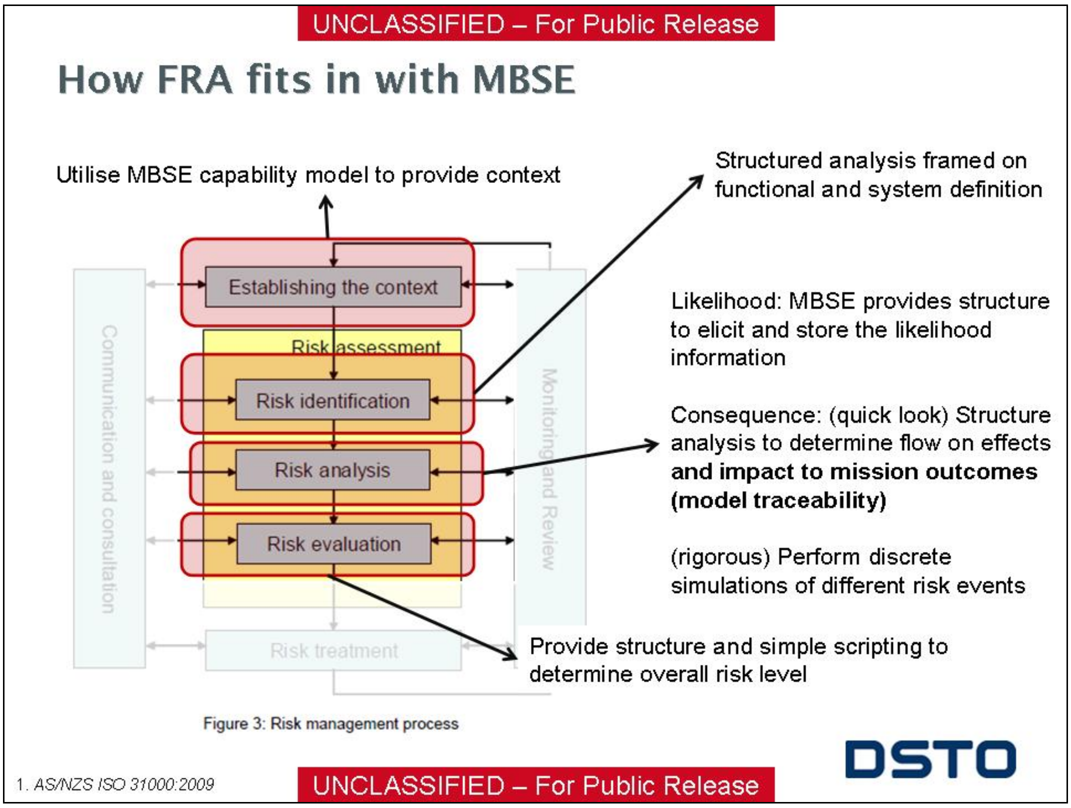
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How FRA fits in with MBSE
Utilise MBSE capability model to provide context
Structured analysis framed on functional and system definition
Establishing the context
Risk assessment
Risk identification
Risk analysis
Risk evaluation
Risk treatment
Communication and consultation
Monitoring and Review
Likelihood: MBSE provides structure to elicit and store the likelihood information
Consequence: (quick look) Structure analysis to determine flow on effects **and impact to mission outcomes (model traceability)**
(rigorous) Perform discrete simulations of different risk events
Provide structure and simple scripting to determine overall risk level
Figure 3: Risk management process
1. AS/NZS ISO 31000:2009
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Required model state

- Functional decomposition defined
- Functional flows modelled
- Information flows modelled and connected to functions

Required for EFFBD representation

If a materiel system does not exist:

- Perform risk analysis on available technologies to perform functions
- Identify *indicative risk areas* in achieving functional and operational outcomes due to technology maturity issues
- Repeat FRA when the materiel system is known.

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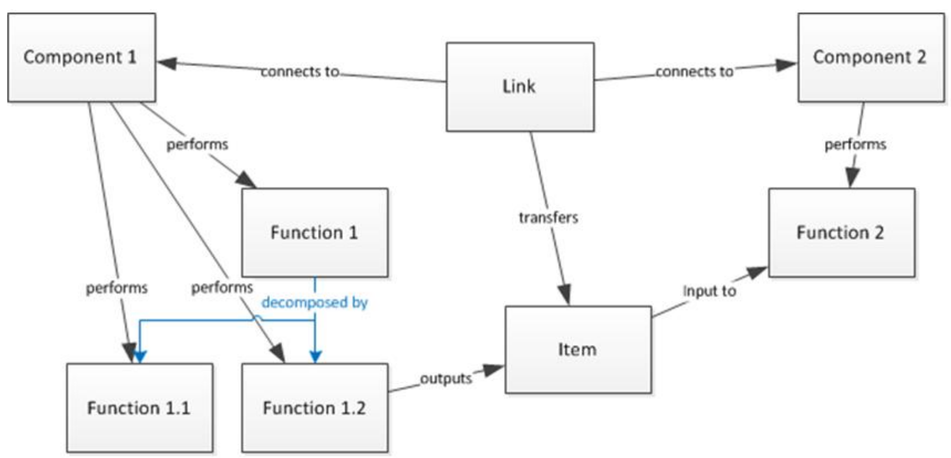
Model elements and relationships



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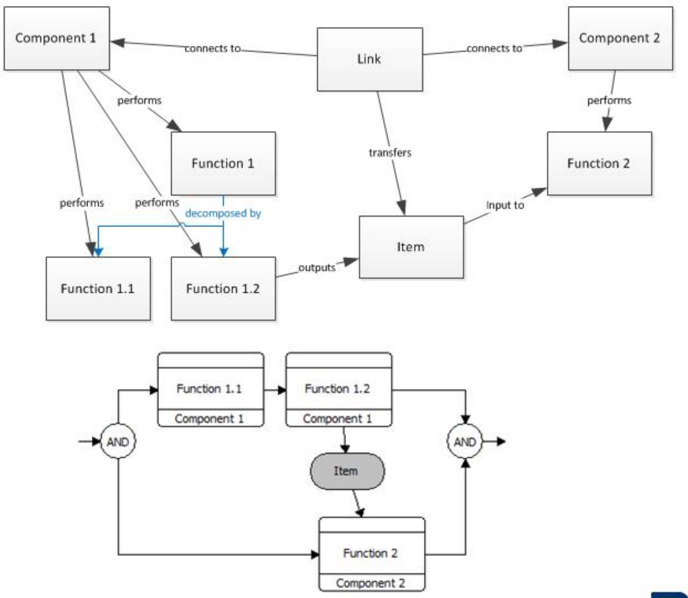
Model elements and relationships



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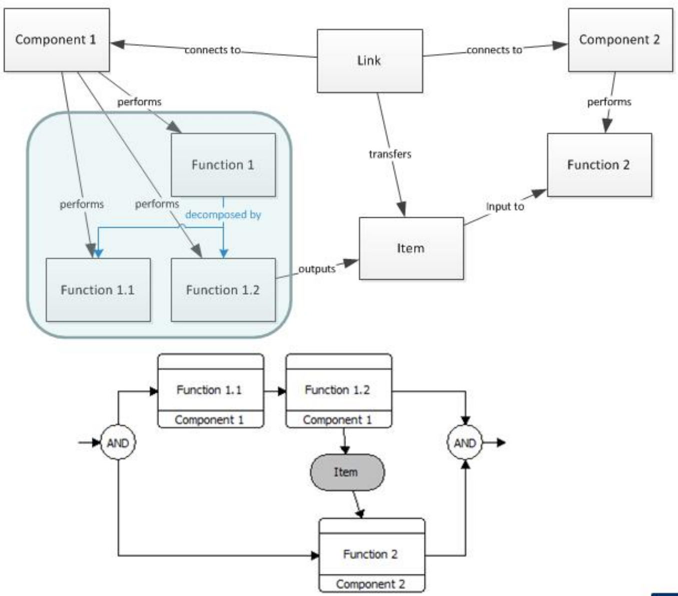
Functional Decomposition



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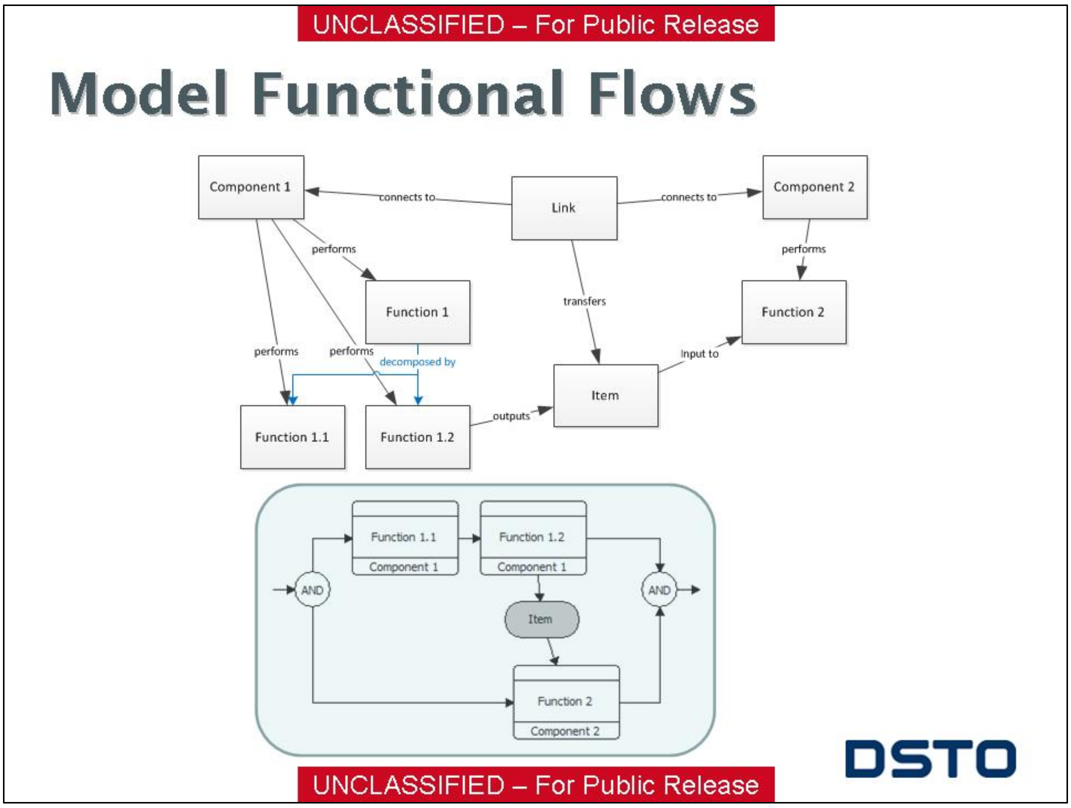
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Model Functional Flows
Component 1
connects to
Link
connects to
Component 2
performs
Function 1
transfers
performs
Function 2
performs
performs
decomposed by
Item
Input to
Function 1.1
Function 1.2
outputs
Function 1.1
Component 1
Function 1.2
Component 1
AND
AND
Item
Function 2
Component 2
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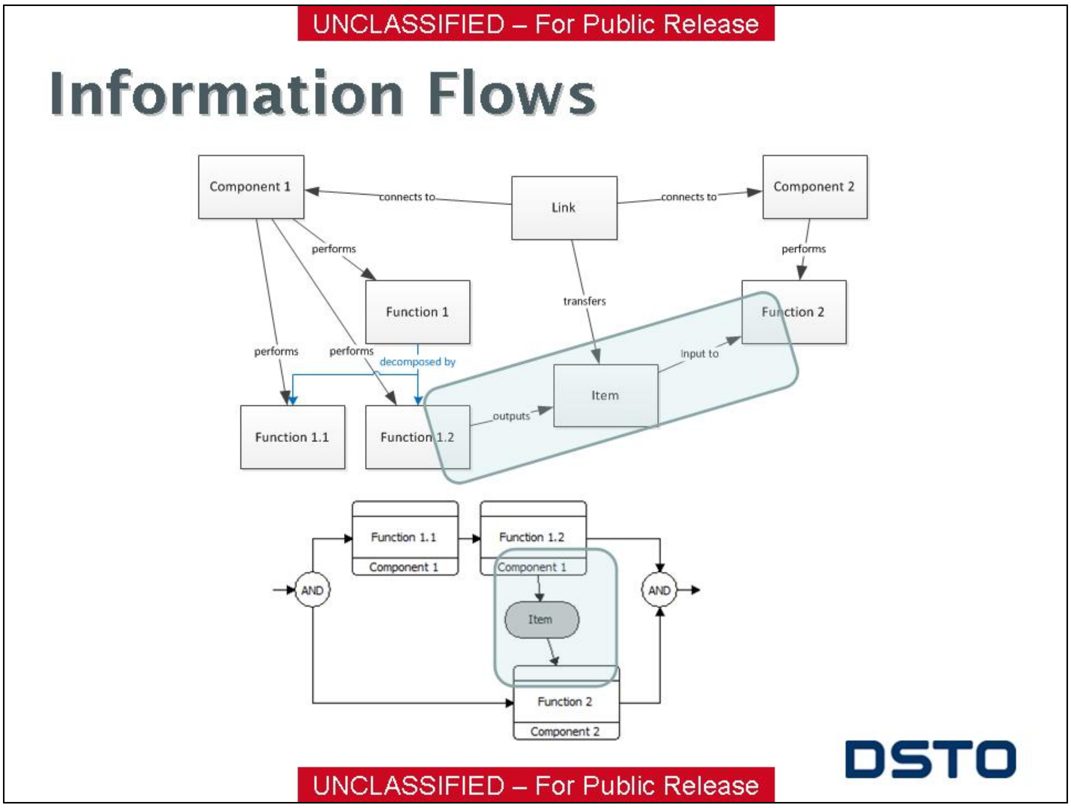
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Information Flows
Component 1
connects to
Link
connects to
Component 2
performs
Function 1
transfers
performs
Function 2
performs
performs
decomposed by
Item
Input to
Function 1.1
Function 1.2
outputs
Function 1.1
Component 1
Function 1.2
Component 1
AND
AND
Item
Function 2
Component 2
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FRA Process
(Modified FMEA Process)

1. Determine objectives
   - To identify, analyse and evaluate risks related to technical readiness
2. Identify starting points for analysis *(mode)*
3. Identify *upstream mechanisms* (causes)
4. Identify *downstream effects* (impact on system performance and mission outcomes)
5. Analyse and record overall risk **(trace to affected mission outcomes)**

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3. Consider upstream causes of functional failure

- Use tool support to produce report on "success path"
- Start from chosen function, consider:
  - *"triggered by"* items: Will always impact flow
  - *"inputs"* items: May affect quality of flow
- For the items collected, consider the other functions they are *"output from"*:
  - If multiple *"output from"*: Redundancies in path
- Continue backwards through the success path

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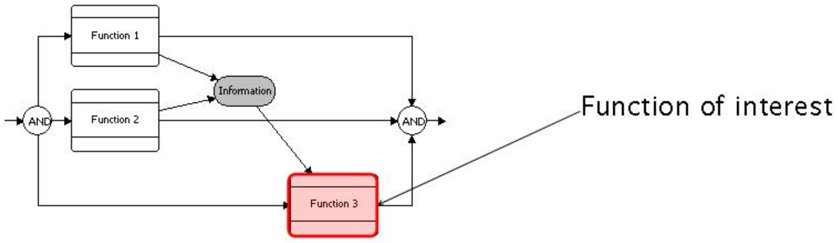
Upstream risk patterns

Redundancy – decreased likelihood



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4. Consider downstream effects of functional failure

- Use tool support to produce report on “success path”
- For each function, consider the items it *“outputs”*
- For each item, consider:
  - *“triggers”* functions: May impact flow, but also need to consider if other functions are able to output this item
  - *“input to”* functions: May affect quality of flow
- Continue forward through the success path

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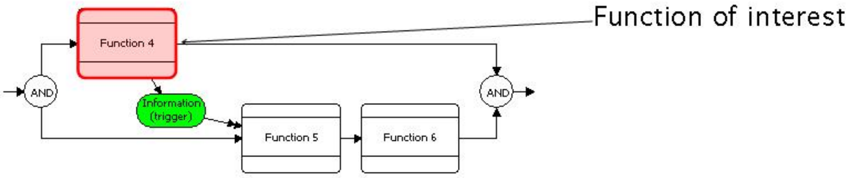
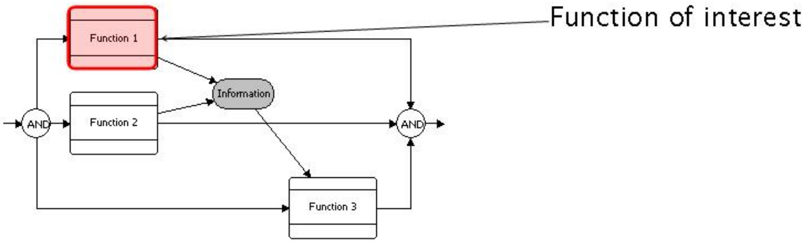
Downstream risk patterns

Critical path – significant consequence



Redundancy – decreased consequence



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Analyse and record resulting risk

- Create technical risk element in the model, related to the Function / Item / Link analysed
- Record risk ratings (likelihood, consequence) and mitigation strategies
- Output Technical Risk documentation from the model

- Risk can result in a design decision and derived Requirement

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5. Analyse and record resulting risk

Likelihood	Consequence/Impact		
	Minor	Moderate	Major
More Than Likely	MEDIUM	HIGH	HIGH
Less Than Likely	LOW	MEDIUM	HIGH
Unlikely	LOW	LOW	MEDIUM

TRAH Risk Likelihood / Impact Matrix

1. *Technical Risk Assessment Handbook*, Project and Requirements Division, DSTO, 2010

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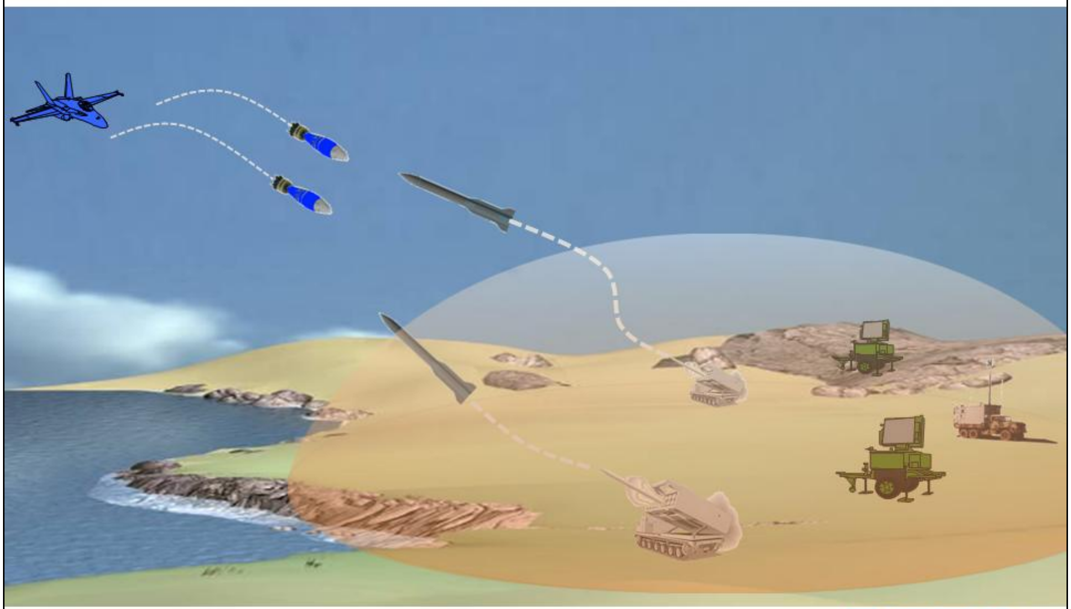
Example – Ground Based Air Defence



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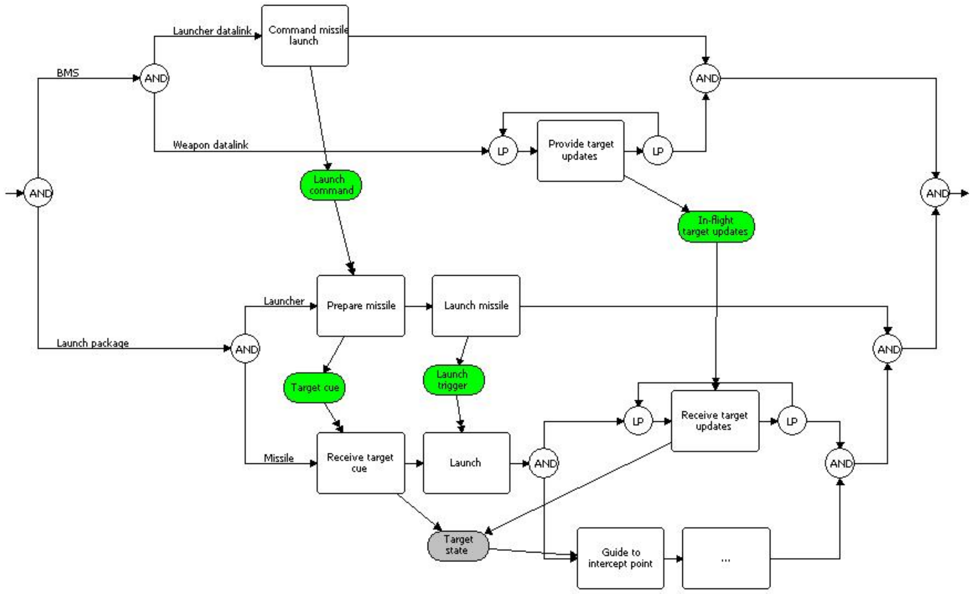
Example – Ground Based Air Defence



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Upstream functional traceability

To guide the analyst in understanding the potential influences on critical functions

What's the likelihood of failure?

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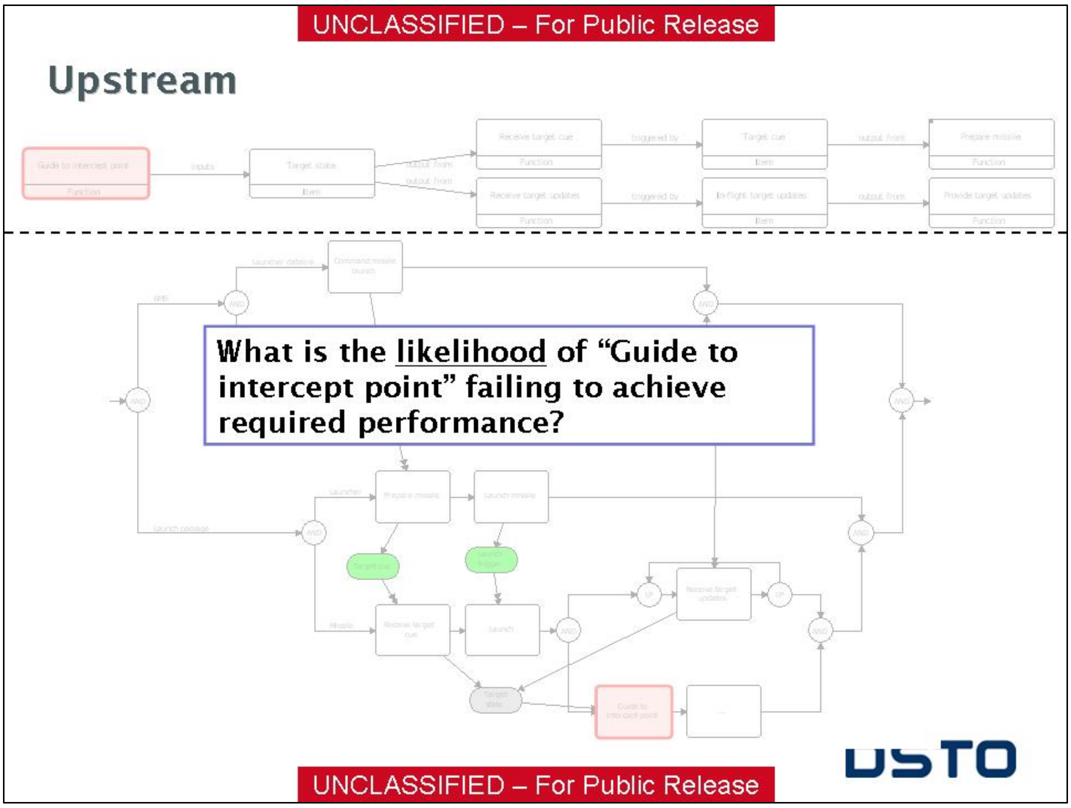
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Upstream
What is the likelihood of “Guide to intercept point” failing to achieve required performance?
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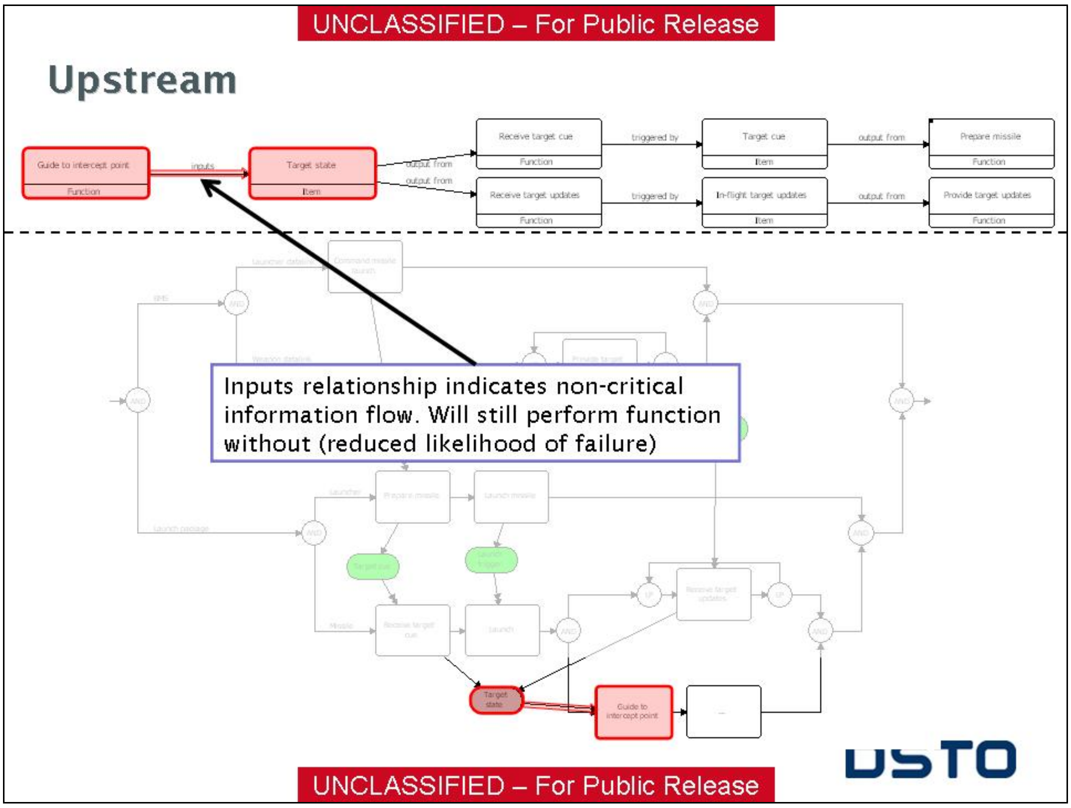
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Upstream
Guide to intercept point
Function
inputs
Target state
Item
output from
output from
Receive target cue
Function
triggered by
Target cue
Item
output from
Prepare missile
Function
Receive target updates
Function
triggered by
In-flight target updates
Item
output from
Provide target updates
Function
Inputs relationship indicates non-critical information flow. Will still perform function without (reduced likelihood of failure)
Target state
Guide to intercept point
...
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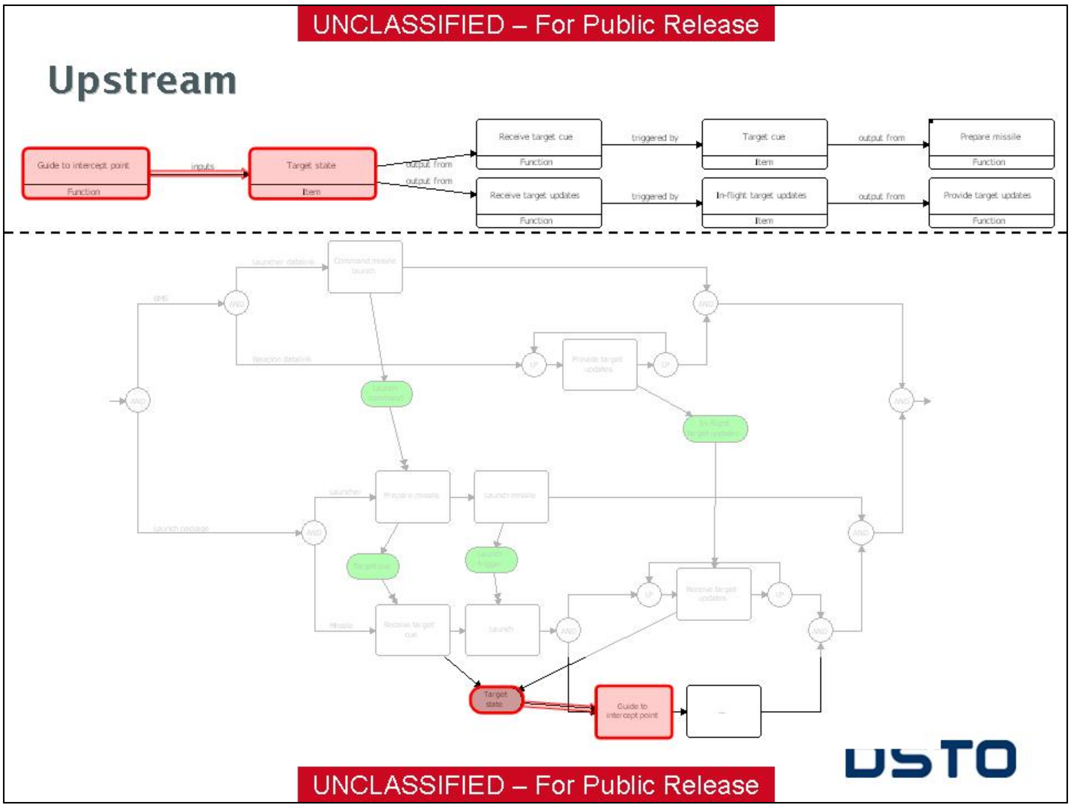
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output from
Provide target updates
Function
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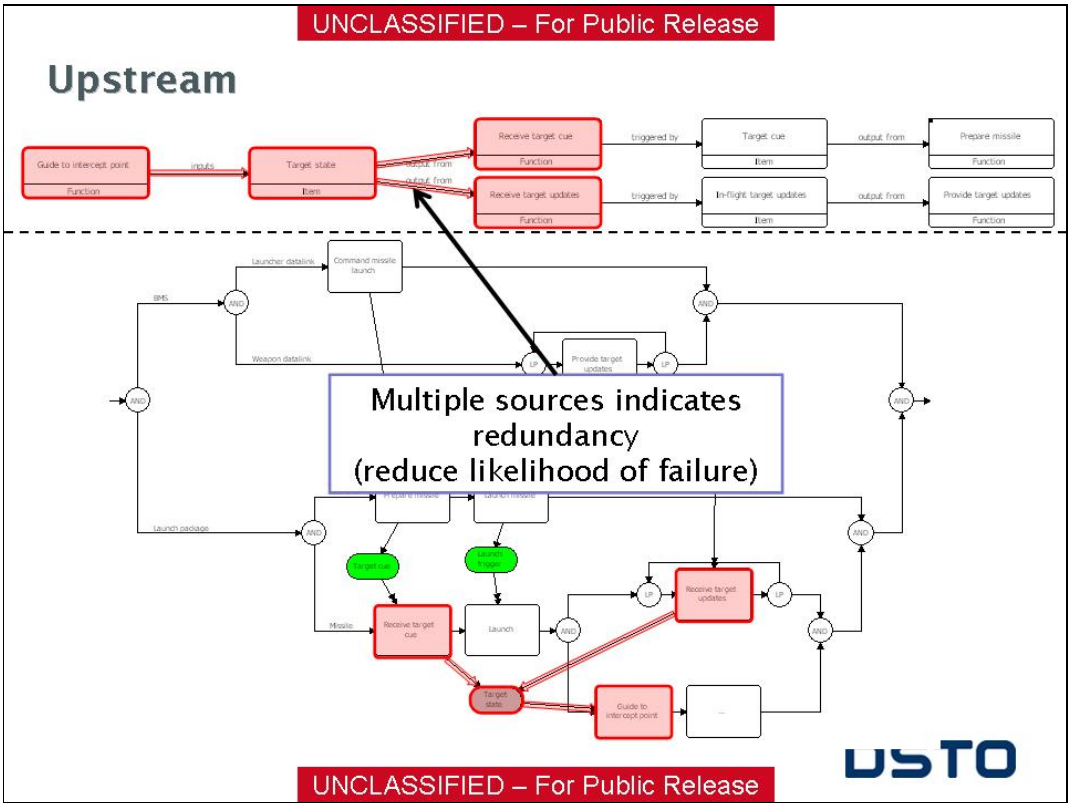
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Upstream
Guide to intercept point
Function
inputs
Target state
Item
output from
output from
Receive target cue
Function
triggered by
Target cue
Item
output from
Prepare missile
Function
Receive target updates
Function
triggered by
In-flight target updates
Item
output from
Provide target updates
Function
Launcher datalink
Command missile launch
BMS
Weapon datalink
Provide target updates
Multiple sources indicates redundancy
(reduce likelihood of failure)
Launch package
Target cue
Launch trigger
Missile
Receive target cue
Launch
Receive target updates
Target state
Guide to intercept point
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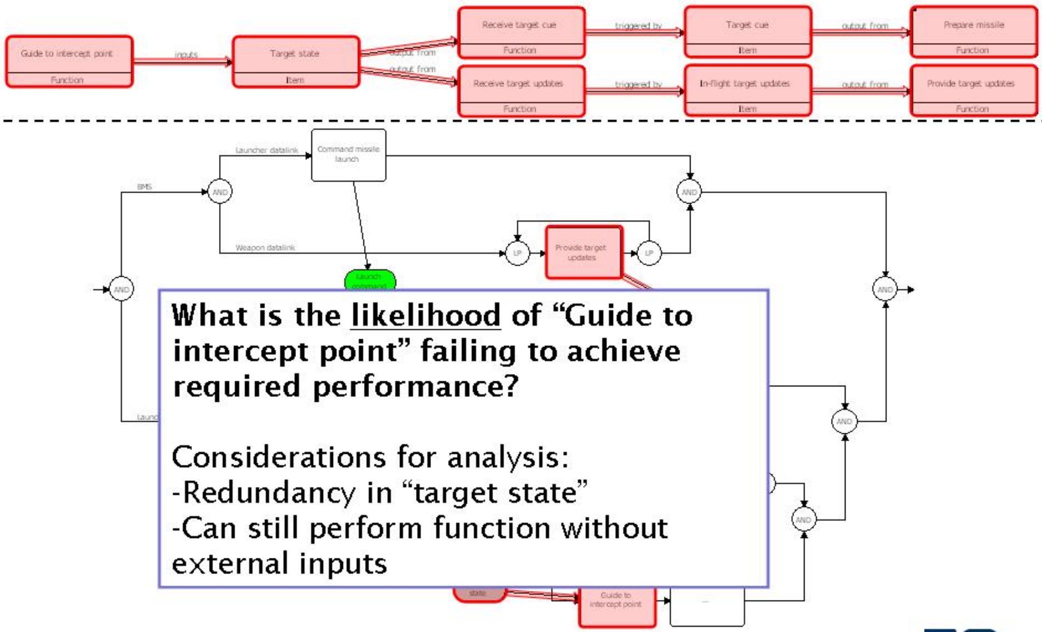
Upstream



What is the likelihood of "Guide to intercept point" failing to achieve required performance?

Considerations for analysis:
-Redundancy in "target state"
-Can still perform function without external inputs

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Downstream functional traceability

To guide the analyst in understanding the potential impact of a system component underperforming

What's the consequence of failure?

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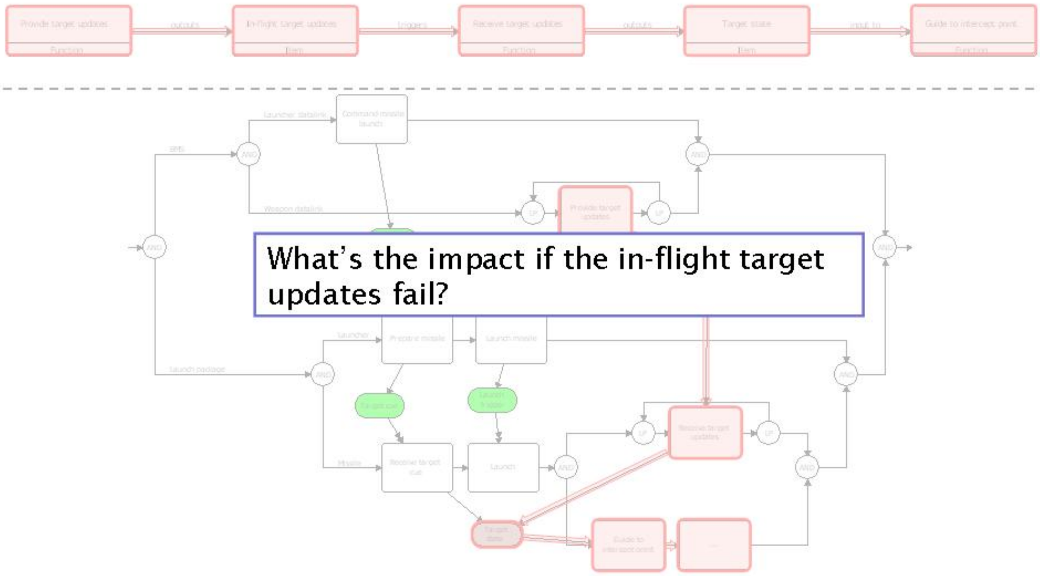
Downstream



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Benefits of methodology/ Conculsions

Issues with current practice	FRA Benefit
TRA templates do not fit every type of acquisition	Focus of risk analysis is on a model of the capability of interest, not on a document template. Documentation is derived from the risk analysis, not the other way around.
Need to assume a materiel solution	FRA can be applied to a functional description of a system using knowledge of available technologies (pre-2nd pass) and is repeated for physical systems at 2nd Pass.
Quality depends on the skills of individuals	Provides a rigorous process to assist in the analysis of whole of system technical risk
Inadequate analysis of: System integration risk Risk coupling	Process guides analyst through the potential influence of technologies on other systems and sub-systems. Focus is on potential impact of integration risk
TRA is a stand-alone document	Analysis performed in and risks recorded in the same model OCD and FPS definitions. Completely traceable: a single source of truth.

Additional Benefits / conclusions

Resulting benefits from using MBSE for risk analysis:

- Capture and trace risks and issues to mission objectives
- Capture non-technical risks/issues (such fitness-for-purpose)
- Can extend FRA process to system assessment
- Resulting derived requirements can be traceable back to the analysis process

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19. Modelling the Management of Systems Engineering Projects

Daniel Spencer and Shaun Wilson
Aerospace Concepts

Abstract

As described in the *INCOSE Systems Engineering Handbook*[18], systems engineering is an interdisciplinary, holistic approach to realise successful systems. It often involves a combined effort of a team of professionals from different disciplines and backgrounds.

The primary role of the Systems Engineering Manager (SEM) of a complex project is to ensure that the technical conduct of the project and the technical products achieve the required quality. The SEM performs this role by defining the technical processes, documentation and output products within the engineering lifecycle of a project through systems engineering management. These aspects of a project are not brought together through any other single management process. Furthermore, systems engineering management supports the other business systems such as project management, engineering management and quality management.

Particularly in early concept development phases of a project, it is important for those involved in Model-Based Systems Engineering (MBSE) to not lose sight of systems engineering management as an enabler of engineering rigour. Engineers can overlook systems engineering management amongst the MBSE methods and technical activities they are conducting.

In his paper at the 2004 INCOSE International Symposium[19], Eric Honour concludes that systems engineering effort improves development quality, cost and schedule compliance, and that systems engineering management is known to be an important part of the systems engineering process. Further to this, improved quality of the systems engineering activity increases these benefits.

The key document used to guide all technical aspects of the project is the Systems Engineering Management Plan (SEMP). The SEMP is now often referred to as a Systems Engineering Plan (SEP), and defines systems engineering organisation, process and products, and also describes speciality engineering integration in a project[20].

A SEMP is an evolving document that captures a project's current systems engineering strategy and its relationship with the overall project management effort. The purpose of the SEMP is to describe the detailed operational plan for executing systems engineering. It also describes how a project organisation will manage technical activities in accordance with

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[18] Haskins, C., ed. 2010 *Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities.* Version 3.2. Revised by M. Krueger, D. Walden, and R. D. Hamelin. San Diego: INCOSE
[19] Honour, E., *Reducing Longterm System Cost by Expanding the Role of the Systems Engineer,* INCOSE International Symposium, France, June 2004.
[20] IEEE, *IEEE Standard for Application and Management of the Systems Engineering Process*, Institute of Electrical and Electronics Engineers 1220-2005, 09 Sept 2005

partners, clients and contractors. All other engineering control documents, such as the Test and Evaluation Master Plan, Configuration Management Plan and Risk Management Plan, are subordinate to the SEMP and must be consistent with it[21]. The SEMP should be established early in the project and updated as necessary to ensure its effectiveness.

This presentation will outline an example of how a model-based systems engineering approach can be taken to represent the systems engineering management aspects of a project, and how the resulting engineering management model can be interrogated to produce the outputs required for a quality SEMP. After describing the underlying structure of the systems engineering management model, an example will demonstrate its use, with a focus on activities taking place in Concept Engineering phases of a project.

This modelling of the project from the point of view of the SEM provides the benefits inherent in the application of MBSE; consistency, traceability, reuse and information sharing. Further to the benefits inherent in the MBSE method, benefits can be gained by facilitating the interface between the management system model and the various engineering models of the project.

Engineering Management plan has a number of benefits that can improve product cost, schedule and quality when used appropriately. By having an approach tailored to the project, and interfacing this in a useful way, the likelihood of its use and the benefits of this use greatly increase.

A robust, complete and consistent SEMP provides clear and unambiguous guidance to systems engineers and technical staff, improves efficiency of the project effort and likelihood of project success. Using a model-based approach to systems engineering management, particularly in a model-based development environment closely couples the systems engineering process and product, allowing clear definition of responsibilities and improved ability for assurance that these responsibilities have been carried out.

Presenter Biographies

Daniel Spencer works as a systems engineer for Aerospace Concepts Pty Ltd. He has over a decade of experience in design and development of systems solutions across a broad range of industries, both in Australia and the United Kingdom. Dan holds a Bachelor of Engineering in Information Technology and Telecommunications from the University of Adelaide. He has been working with Australian Defence clients developing and refining tools and methods for a repeatable and comprehensive MBSE method, while using this approach for real-world capability definition and development projects.

Shaun Wilson is the Chief Executive Officer of aerospace and systems engineering house, Aerospace Concepts Pty Ltd. He is a practising systems engineer with particular expertise in aerospace modelling and simulation and conceptual design. His experience spans from aerospace and defence to mining and leisure sports. Shaun sits on a range of company boards, holds multiple degrees, and is a published in several technical fields.

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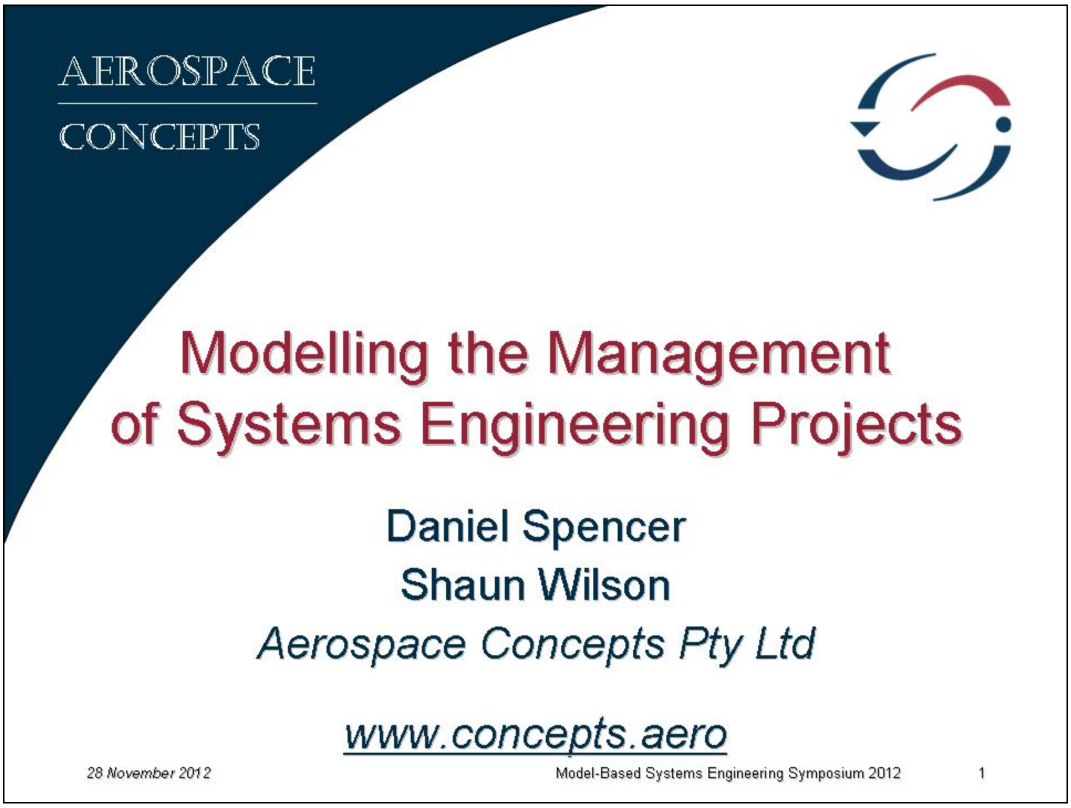
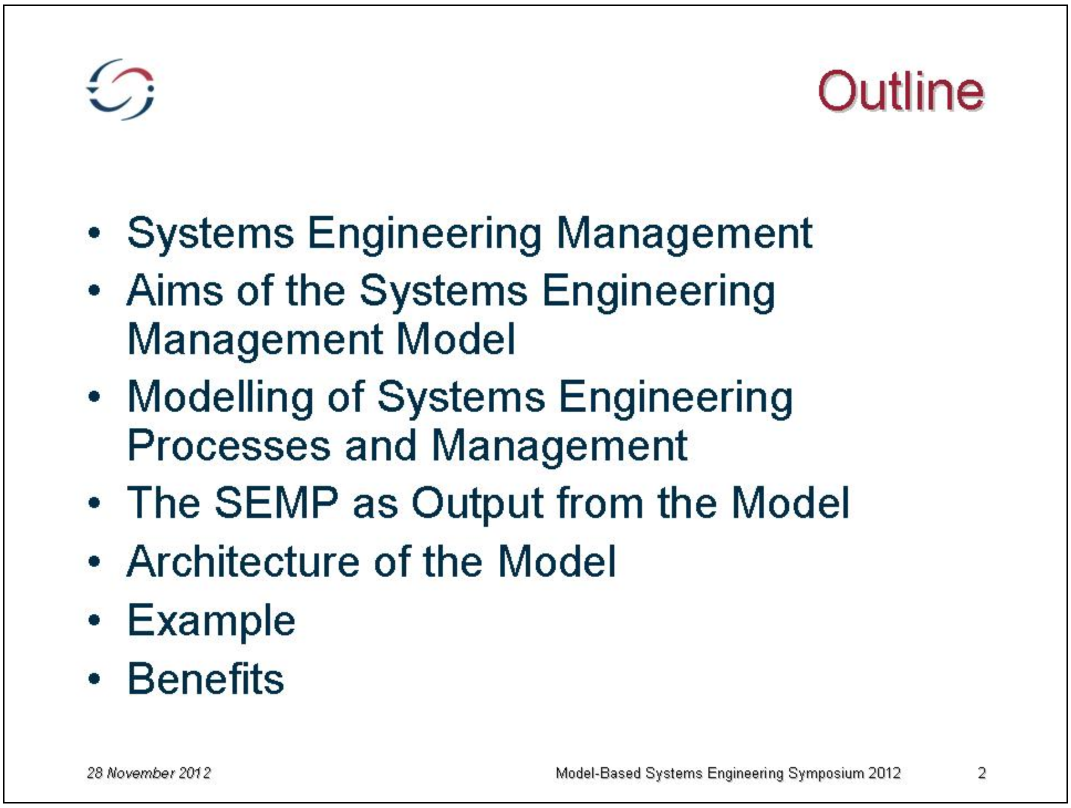
[21] NASA, *Systems Engineering Handbook*, Revision 1, December 2007.

Presentation





Systems Engineering Management Introduction

- NASA Systems Engineering Handbook:

  "Systems engineering management is a technical function and discipline that ensures that systems engineering and all other technical functions are properly applied."
- The goal of the Management Process is to organise the technical effort in the project lifecycle

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Aims of the Systems Engineering Management Model

- Provide a template of the Systems Engineering Processes, Controls and Plans
- Implement this as model of Project Management aspects
  - Specifically concentrating on Systems Engineering Management
  - Linked through MBSE tool to the System and Operational models
- Output SEMP from model
  - Reduce effort and possibilities of inconsistencies when tailoring a SEMP

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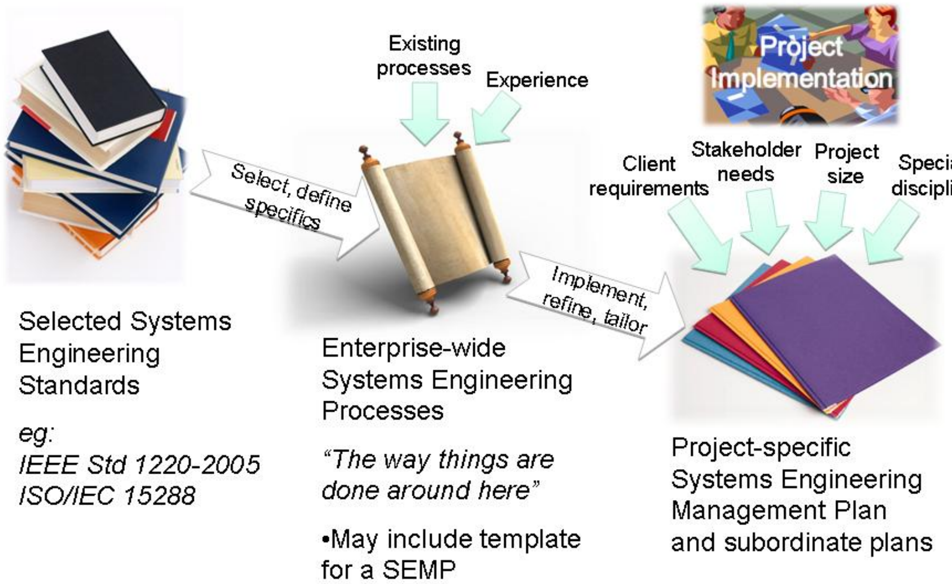
Implementing Systems Engineering Processes



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Modelling Systems Engineering Processes

- A template is made to be modified for implementation
- Key is linking of data together in the model – a change in one place reflects in others
- Have an Enterprise-wide Systems Engineering Process Model
- Instantiate this model for each project, refining, tailoring and extending as required

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Modelling Systems Engineering Management

- The SE Management Model is:
  - A representation of the systems engineering processes and structure
  - Built within a software tool (we have chosen Vitech's CORE, with it's Program Management modules)

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The SEMP as Output from the Model

A *Systems Engineering Management Plan (SEMP)* is the key document used to guide all technical aspects of the project

•It defines SE organisation, process, products, and speciality engineering integration

•An evolving document capturing current SE strategy and relationship with overall Project Management effort

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DoDAF 2.0 Project Viewpoints

- PV-1: Project Portfolio Relationships
  - Represents an organisational perspective on the project
- PV-2: Project Timelines
  - Can be Gantt chart view of the project, including dependencies
- PV-3: Project to Capability Mapping
  - Maps project to capability, showing how elements help to achieve a capability
  - Analogous to SV-5a (Operational Activity to System Function Traceability Matrix)
- UPDM provides a standardised way for representing these viewpoints

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SEMP Viewpoints on the Model

- Work Breakdown Structure
  - Hierarchy of all work packages for the project
  - *Systems Eng Processes and Controls are a part of this WBS*
- Descriptions of each Systems Engineering Process and Control
  - Process and Control descriptions
  - Activity models allowing Flow-Block Diagram outputs
  - Responsibilities linking to Engineering Organisations
- Implementations of the three DoDAF 2.0 Project Viewpoints
  - PV-1 to describe the Engineering Organisations, including:
    - Engineering authority and delegation of responsibility
    - Defined relationships with subcontractors, suppliers etc
  - PV-2 to bring all work packages together in an Engineering Schedule
    - *via higher-level activity model for the overall project*
  - PV-3 to map Activities to Engineering Deliverables and Capabilities

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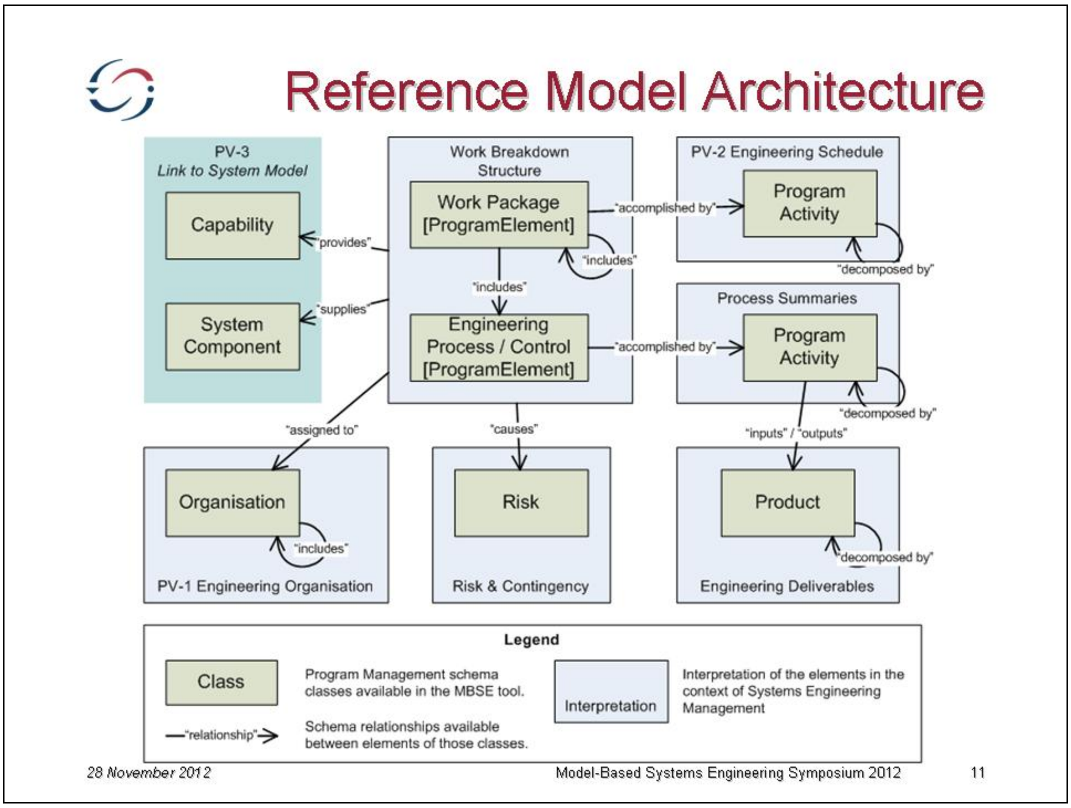
Reference Model Architecture
PV-3
Link to System Model
Capability
System Component
Work Breakdown Structure
Work Package [ProgramElement]
Engineering Process / Control [ProgramElement]
PV-2 Engineering Schedule
Program Activity
Process Summaries
Program Activity
"provides"
"supplies"
"accomplished by"
"includes"
"decomposed by"
"assigned to"
"causes"
"inputs" / "outputs"
Organisation
"includes"
PV-1 Engineering Organisation
Risk
Risk & Contingency
Product
"decomposed by"
Engineering Deliverables
Legend
Class
Program Management schema classes available in the MBSE tool.
"relationship"
Schema relationships available between elements of those classes.
Interpretation
Interpretation of the elements in the context of Systems Engineering Management
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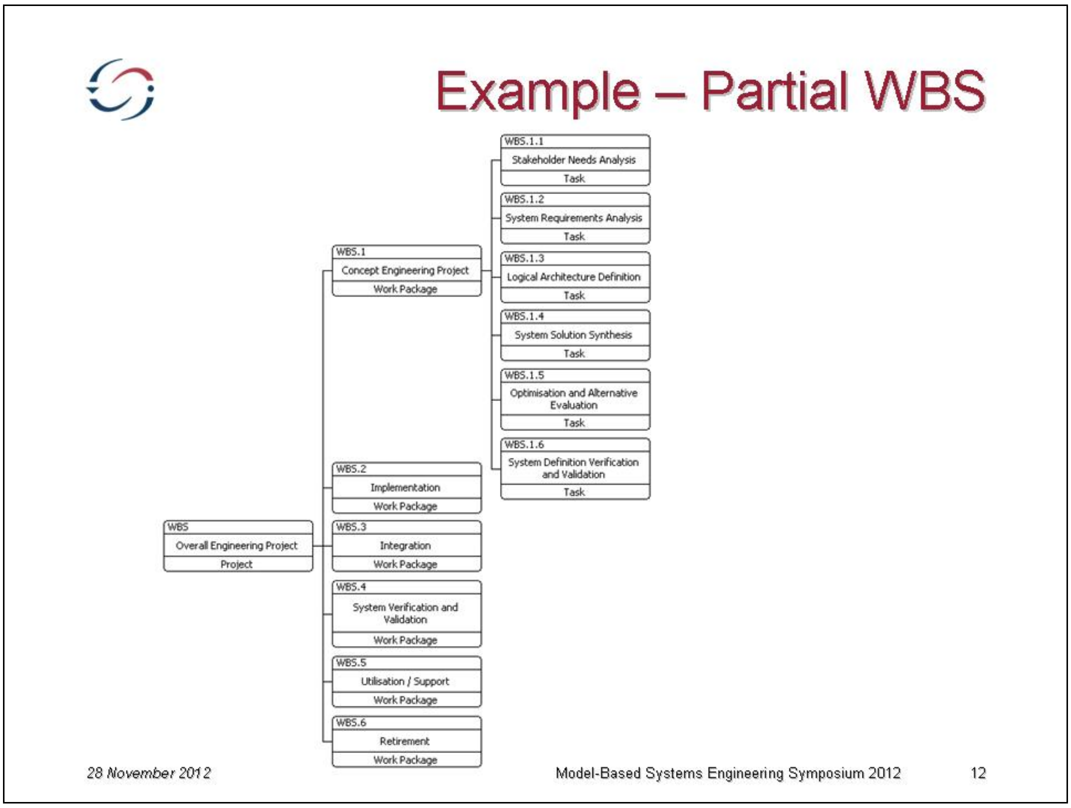
Example – Partial WBS
WBS
Overall Engineering Project
Project
WBS.1
Concept Engineering Project
Work Package
WBS.1.1
Stakeholder Needs Analysis
Task
WBS.1.2
System Requirements Analysis
Task
WBS.1.3
Logical Architecture Definition
Task
WBS.1.4
System Solution Synthesis
Task
WBS.1.5
Optimisation and Alternative Evaluation
Task
WBS.1.6
System Definition Verification and Validation
Task
WBS.2
Implementation
Work Package
WBS.3
Integration
Work Package
WBS.4
System Verification and Validation
Work Package
WBS.5
Utilisation / Support
Work Package
WBS.6
Retirement
Work Package
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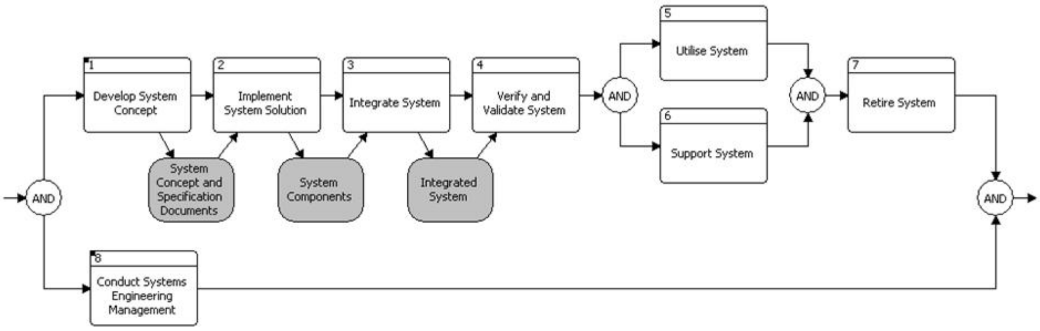
Example – Overall Engineering Activity Model



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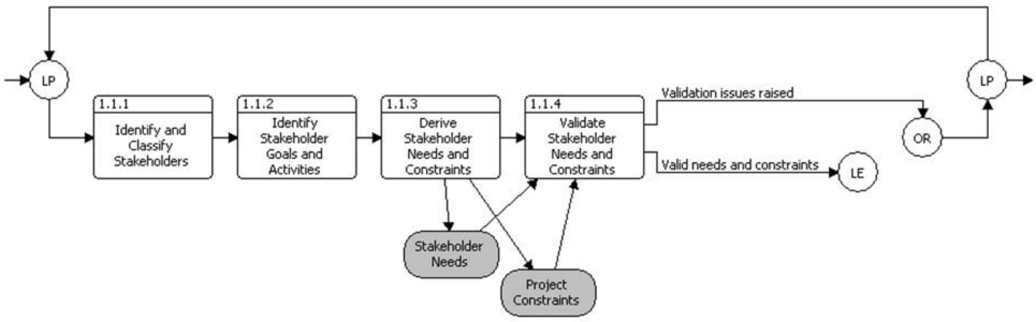
Example – Process Summary Activity Model

- Analyse Stakeholder Needs activity



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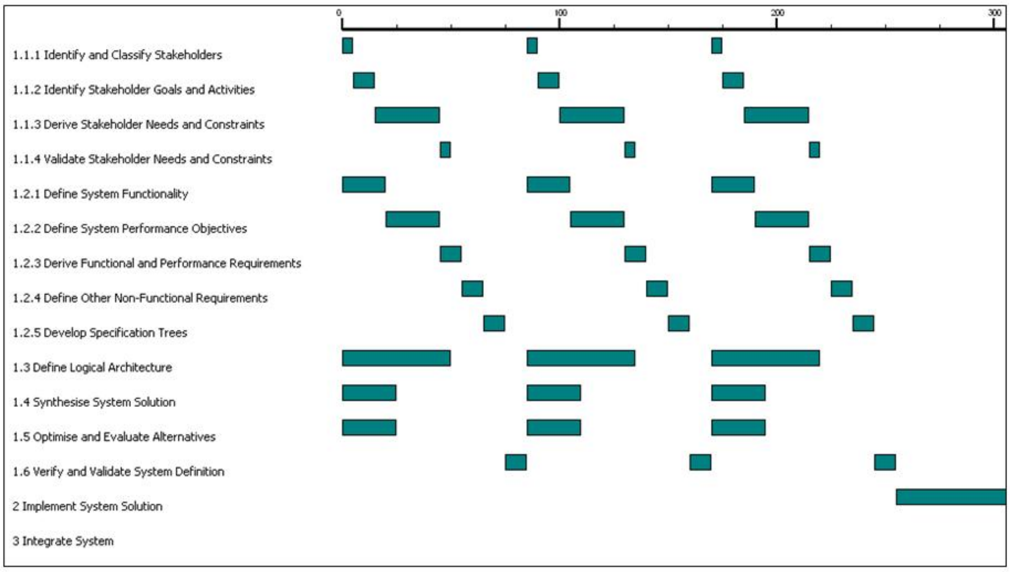
Example – Engineering Schedule



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The Alternative

- Document-based approach to developing a SEMP
  - Systems Engineering approach not linked to WBS or master schedule
  - Responsibilities not linked to project organisation
  - System Engineering tasks not linked to capability
- In the alternative approach, changes made to these aspects of the SEMP need to be made in multiple places

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Benefits of the Modelling Approach

- Common benefits of MBSE approach:
  - Consistency
  - Traceability
  - Reuse
  - Information sharing
- Interfacing models through an MBSE tool
  - Between Management Model and various engineering and technical models
  - Clearly define responsibilities
  - Improve abilities for assurance on these responsibilities
- Produce a more robust, complete and consistent SEMP

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Benefits of a robust SEMP

- Provide clear, unambiguous guidance to technical staff
- Improve efficiency of project effort
- Improve capability quality, cost and schedule

The bottom line

- Improve likelihood of project success

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AEROSPACE
CONCEPTS

Questions?

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www.concepts.aero

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20. Potential Benefits Of Product Lifecycle Management (PLM) 2.0 Social Networking Capabilities Within MBSE

Axel Reichwein[1] and Shaunak Hemant Shroff[2]
[1]KONEKSYS and [2]MEMKO

Abstract

The reuse of Web 2.0 concepts in the context of product development has been coined "PLM 2.0". Its goal is to facilitate and enhance the collaboration between engineers, end users and project managers. PLM 2.0 provides a transparent communication platform for knowledge sharing and knowledge creation between communities which were previously disconnected such as engineers and end users. As a result, all stakeholders can take a more active role during product development. Clients and end users can for example easily follow the design evolution and verify that their design intent is being met.

As of now, PLM 2.0 concepts have been embedded in engineering software applications such as CAD and PLM systems as well as in Microsoft Office documents. However, many products are increasingly composed of software and electronics which require other design representations than plain 3D models and documents. For instance, a system architecture description is particularly useful in complex systems design to represent at a high level of abstraction the main system components and interactions. Multiple stakeholders from different disciplines as well as the clients and end users can then better identify interface issues and design change impacts.

The paper provides a brief introduction to PLM 2.0 concepts with respect to social communication and explores some of the key features. It further delves into usage scenarios of PLM 2.0 technology and explores the benefits of such technology in a general perspective of the company. More specifically, an example of using PLM 2.0 in early stages of Systems Engineering activities and usage across a SysML example is explored.

The Systems Modelling language (SysML) is increasingly used in Model-Based Systems Engineering (MBSE) to define the system architecture, requirements, functions, use cases and behaviour and cross-cutting dependencies. This article investigates the potential benefits of supporting PLM 2.0 social networking capabilities within a SysML modelling environment in order to improve: the collaboration between clients/end users and system engineers, the communication between system engineers and engineers from other disciplines, the traceability and consistency between design representations at multiple abstraction levels including requirements, system architecture, PLM, CAD and simulation models.

Since the human factor is critical in reaching PLM 2.0 benefits, criteria are listed to enable social computing to reach its fullest potential within the systems engineering community. Two major factors are critical for the success of social technologies in engineering: company culture and communicative engineers. Without a company culture facilitating and encouraging healthy discussion, engineers will not use PLM 2.0. In addition, the value of PLM 2.0 relies on clear and qualitative contributions from engineers. The communication skills of engineers will therefore become more important as social technologies are increasingly adopted.

Presenter Biographies

Axel Reichwein received a PhD in Aerospace Engineering from the University of Stuttgart focusing on multidisciplinary system modelling, data integration, and model-driven system configuration using the Unified Modelling Language (UML). Pursuing his research interests, Dr. Reichwein continued as a Postdoctoral Research Associate at the Georgia Institute of Technology with Dr. Chris Paredis focusing on the Systems Modeling Language (SysML). His research was sponsored by Siemens, United Technologies, John Deere, Ford Motor Company, and DARPA.

During his PhD and Post-doctorate research, he implemented several model transformations between UML/SysML and discipline-specific models (CAD: CATIA, SolidWorks, VRML; Dynamic System Simulation: Simulink, SimMechanics, Modelica; Mathematical Solvers: MATLAB, Mathematica, GAMS; Other: Excel). These model transformations were implemented using standard programming languages such as Java as well as new emerging model transformation languages such as Query/View/Transformation (QVT).

Axel Reichwein also actively participated in the Object Management Group (OMG) by chairing the OMG SysML-Modelica project and by contributing to the Systems Modelling Language (SysML) working groups.

Shaunak Hemant Shroff completed a Bachelor of Engineering (Mechatronics) and Bachelor of Computer Science from the University of Melbourne with first class honours. He developed a model based Simulink Architecture in order to define the behaviour of the Sumo Robot. The Sumo Robot won two competitions (held in Melbourne and Sydney).

He works for Memko Pty Ltd. which is a value-added reseller of Dassault Systemes' Product Lifecycle Management (PLM) software and is well versed in using Systems Engineering software such as CATIA V6 Systems, Dymola, ControlBuild and Rectify. As a certified V6 Foundations User, he has the knowledge on the basis and concepts of the PLM 2.0 architecture and its impact on the Systems Engineering Software.

He has had also some experience in integrating Dassault Systemes software with other third party software through the usage of the inbuilt scripting functionalities.

Presentation

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KONEKSYS

POTENTIAL BENEFITS OF PLM 2.0 SOCIAL NETWORKING CAPABILITITES WITHIN MBSE

AXEL REICHWEIN (CEO, KONEKSYS)
SHAUNAK SHROFF (PLM ENGINEER, MEMKO)

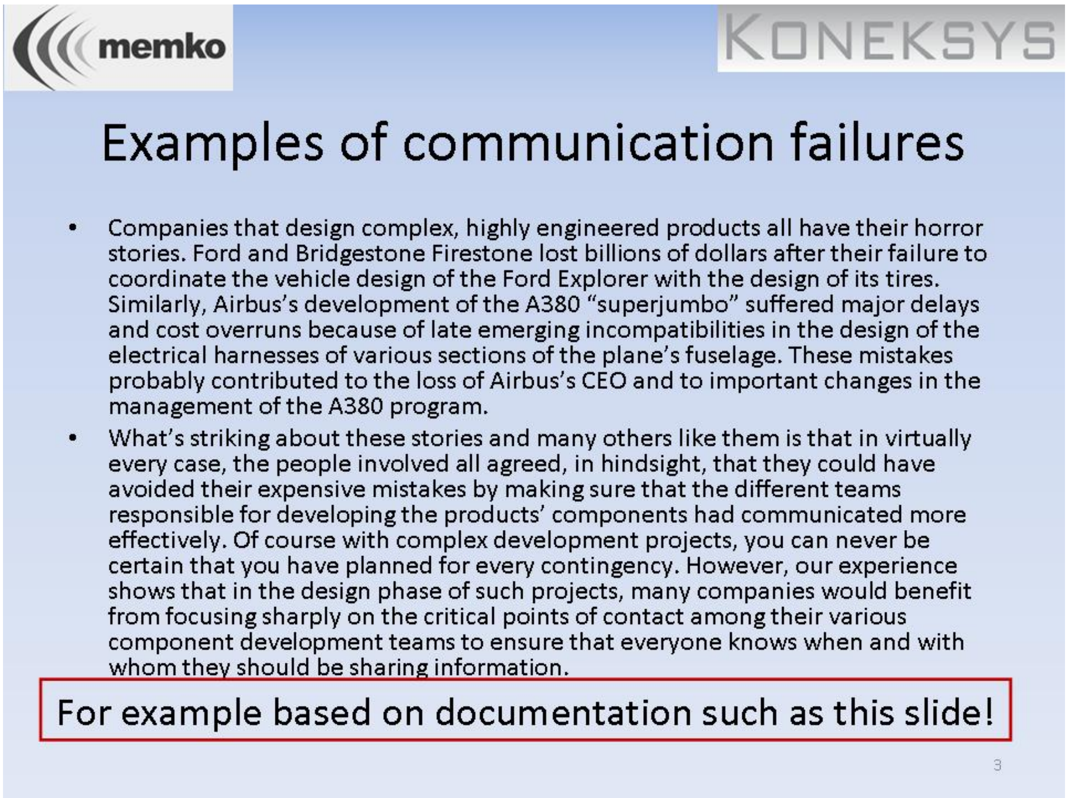
memko

KONEKSYS

Overview

- Communication in Engineering
- Overcoming communication barriers through social technologies
- Social technologies for MBSE 2.0
- Roadblocks for MBSE 2.0
- Conclusion

2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KONEKSYS
Examples of communication failures
• Companies that design complex, highly engineered products all have their horror stories. Ford and Bridgestone Firestone lost billions of dollars after their failure to coordinate the vehicle design of the Ford Explorer with the design of its tires. Similarly, Airbus's development of the A380 "superjumbo" suffered major delays and cost overruns because of late emerging incompatibilities in the design of the electrical harnesses of various sections of the plane's fuselage. These mistakes probably contributed to the loss of Airbus's CEO and to important changes in the management of the A380 program.
• What's striking about these stories and many others like them is that in virtually every case, the people involved all agreed, in hindsight, that they could have avoided their expensive mistakes by making sure that the different teams responsible for developing the products' components had communicated more effectively. Of course with complex development projects, you can never be certain that you have planned for every contingency. However, our experience shows that in the design phase of such projects, many companies would benefit from focusing sharply on the critical points of contact among their various component development teams to ensure that everyone knows when and with whom they should be sharing information.
For example based on documentation such as this slide!
3


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Communication in Engineering
• Importance of Communication
– Engineering is about making good decisions
– Engineered systems are becoming complex
• Communication barriers :
– Ineffectiveness of the current communication channels;
– Restrictions on expressiveness imposed by notations; and
– Social and organisational barriers.
4

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How can social technologies break communication barriers?

- Taking advantage of social Web 2.0 –based technologies
  - It becomes easier for everyone to connect with everyone
  - Harvesting collective intelligence
  - Making communication more transparent and easier
  - Adding context to the discussion thread (not just a simple forum)

- Web 2.0 Examples
  - Amazon user reviews
  - Wikipedia articles
  - Facebook
  - Twitter

Social technologies applied to Engineering: PLM 2.0!

5

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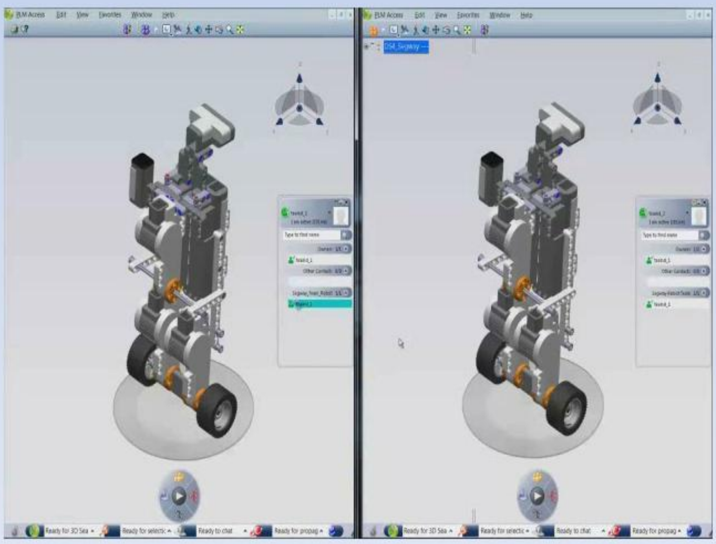
PLM 2.0 Example



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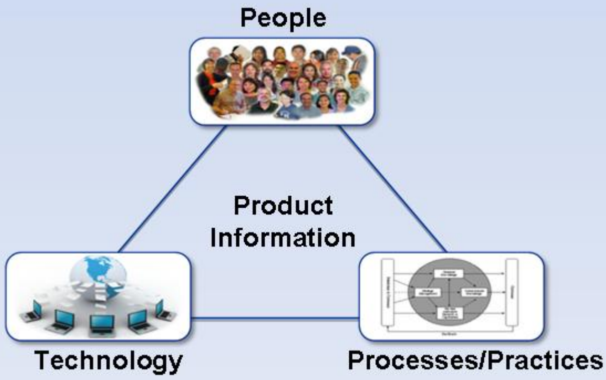
PLM 2.0

PLM (Product Lifecycle Management) is a concept/technology that centers around product development from conception to completion.



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PLM 2.0 Features

- Instant Collaboration in real-time
- Distribution of information to right channels
- Adopts web services architecture
- Use of 3D models for communication
- Data Interoperability
- On demand access to data - searchability

8

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PLM 2.0 Usage Scenarios

- Start a discussion thread related to a model feature
  - Ask product developement questions
  - Get help on design issues
  - Solicit feedback from a broad or narrow audience
  - Ask for clarification on a specific feature
  - Make suggestions
  - Propose fixes
- Participate in a discussion
  - Participate in brainstorming activities
  - Give feedback
  - Share best practices

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PLM 2.0 Benefits

- More transparent communication
- Ensuring decision making and process information is readily communicated
- Less time spent in meetings
- Better understanding of the history leading to a decision
- Benefits of Service Oriented Architecture

PLM 2.0 for Model-Based Systems Engineering?

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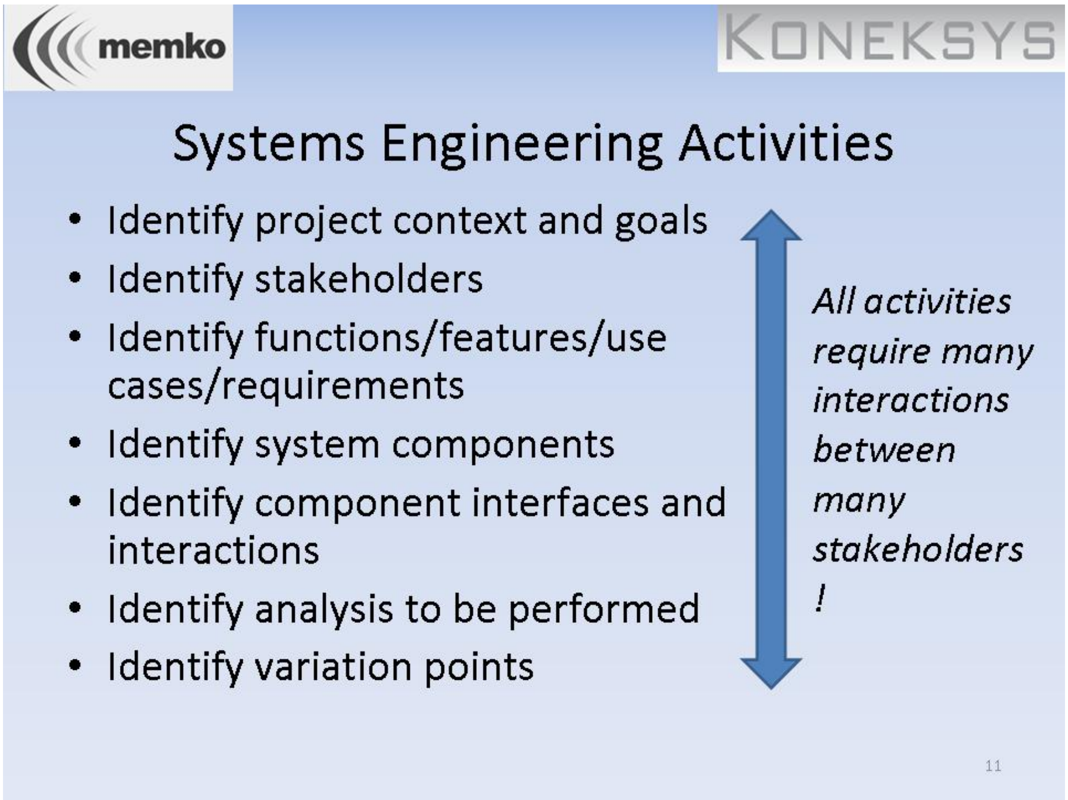
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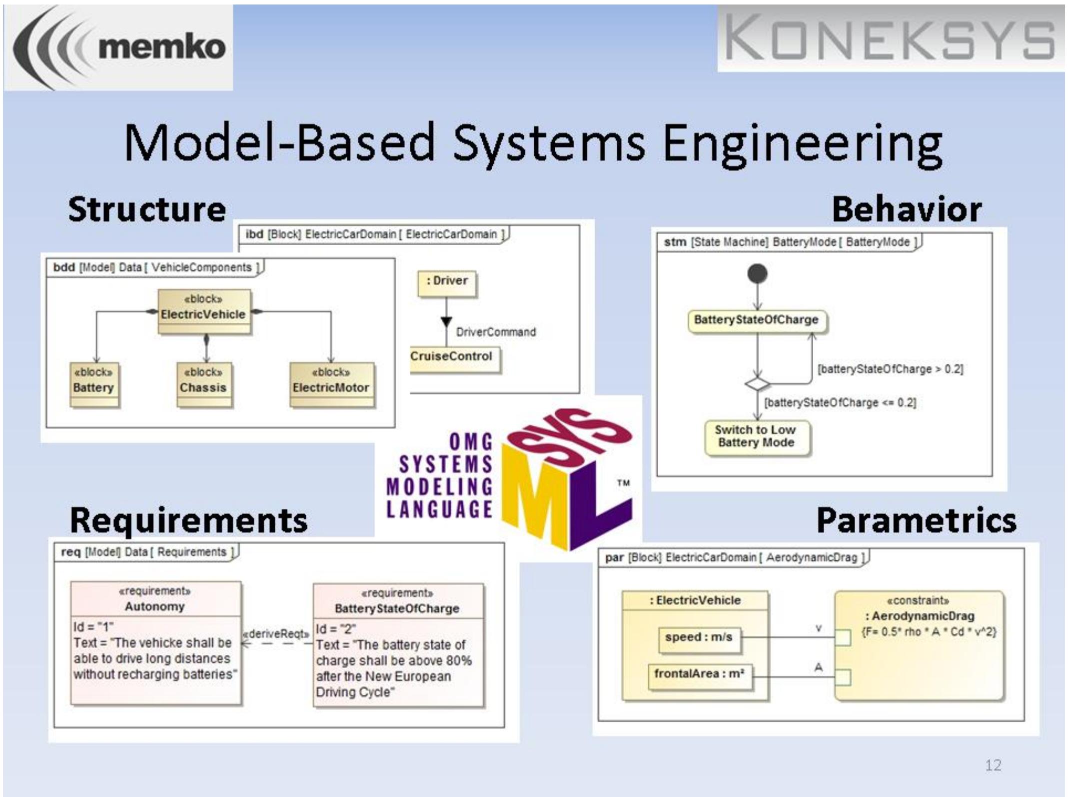
Systems Engineering Activities
• Identify project context and goals
• Identify stakeholders
• Identify functions/features/use cases/requirements
• Identify system components
• Identify component interfaces and interactions
• Identify analysis to be performed
• Identify variation points
All activities require many interactions between many stakeholders !
11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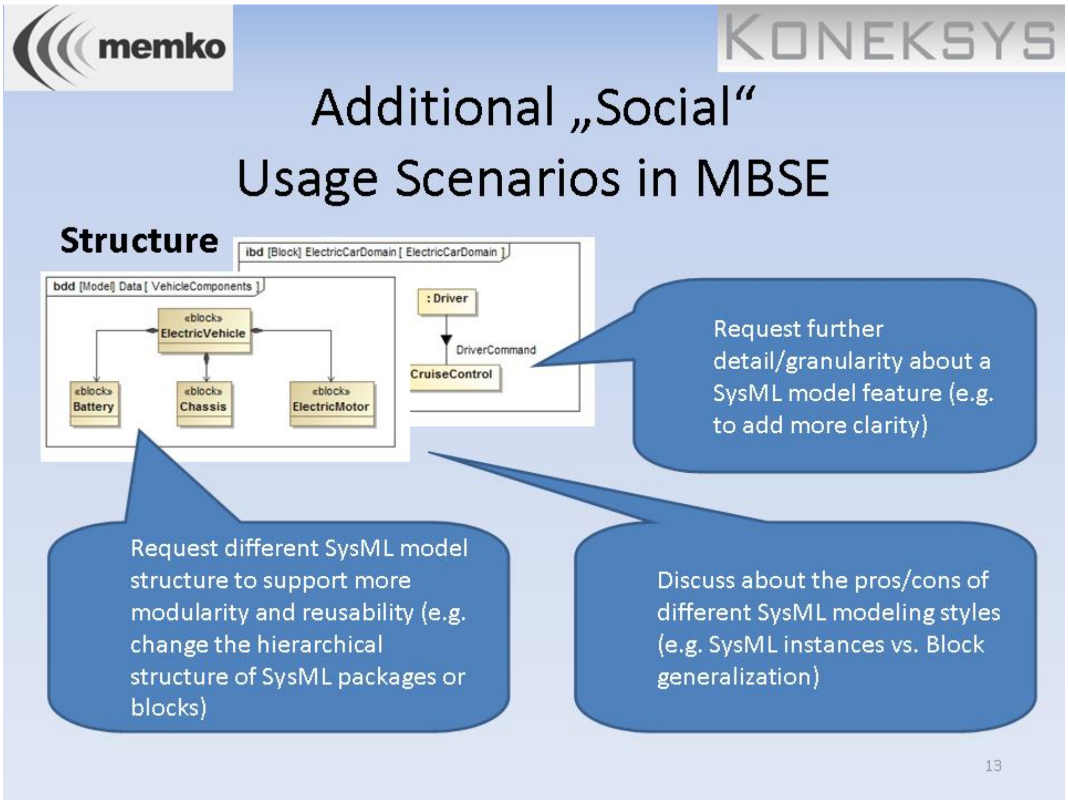
Model-Based Systems Engineering
Structure
Behavior
bdd [Model] Data [VehicleComponents]
«block» ElectricVehicle
«block» Battery
«block» Chassis
«block» ElectricMotor
ibd [Block] ElectricCarDomain [ElectricCarDomain]
: Driver
DriverCommand
CruiseControl
stm [State Machine] BatteryMode [BatteryMode]
BatteryStateOfCharge
[batteryStateOfCharge > 0.2]
[batteryStateOfCharge <= 0.2]
Switch to Low Battery Mode
OMG SYSTEMS MODELING LANGUAGE
SysML TM
Requirements
Parametrics
req [Model] Data [Requirements]
«requirement» Autonomy
Id = "1"
Text = "The vehicke shall be able to drive long distances without recharging batteries"
«deriveReqt»
«requirement» BatteryStateOfCharge
Id = "2"
Text = "The battery state of charge shall be above 80% after the New European Driving Cycle"
par [Block] ElectricCarDomain [AerodynamicDrag]
: ElectricVehicle
speed : m/s
frontalArea : m²
«constraint» : AerodynamicDrag
{F= 0.5* rho * A * Cd * v^2}
v
A
12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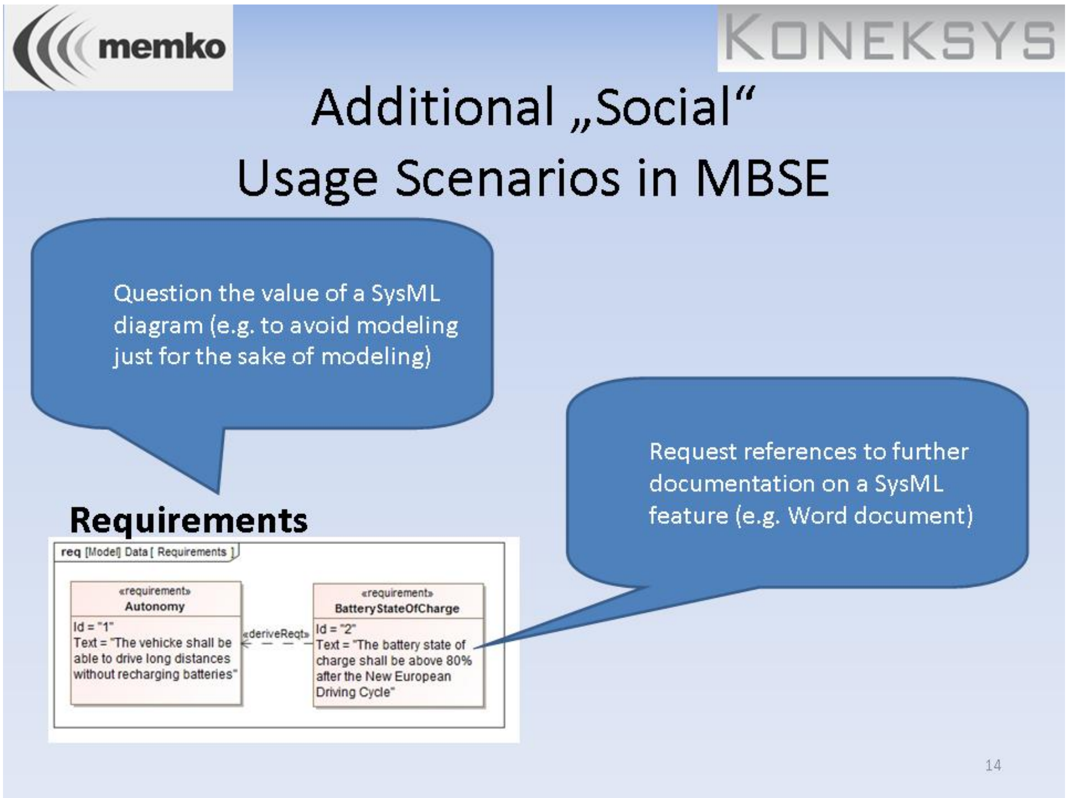
Additional „Social“
Usage Scenarios in MBSE
Structure
ibd [Block] ElectricCarDomain [ElectricCarDomain]
: Driver
DriverCommand
CruiseControl
bdd [Model] Data [VehicleComponents]
«block»
ElectricVehicle
«block»
Battery
«block»
Chassis
«block»
ElectricMotor
Request further detail/granularity about a SysML model feature (e.g. to add more clarity)
Request different SysML model structure to support more modularity and reusability (e.g. change the hierarchical structure of SysML packages or blocks)
Discuss about the pros/cons of different SysML modeling styles (e.g. SysML instances vs. Block generalization)
13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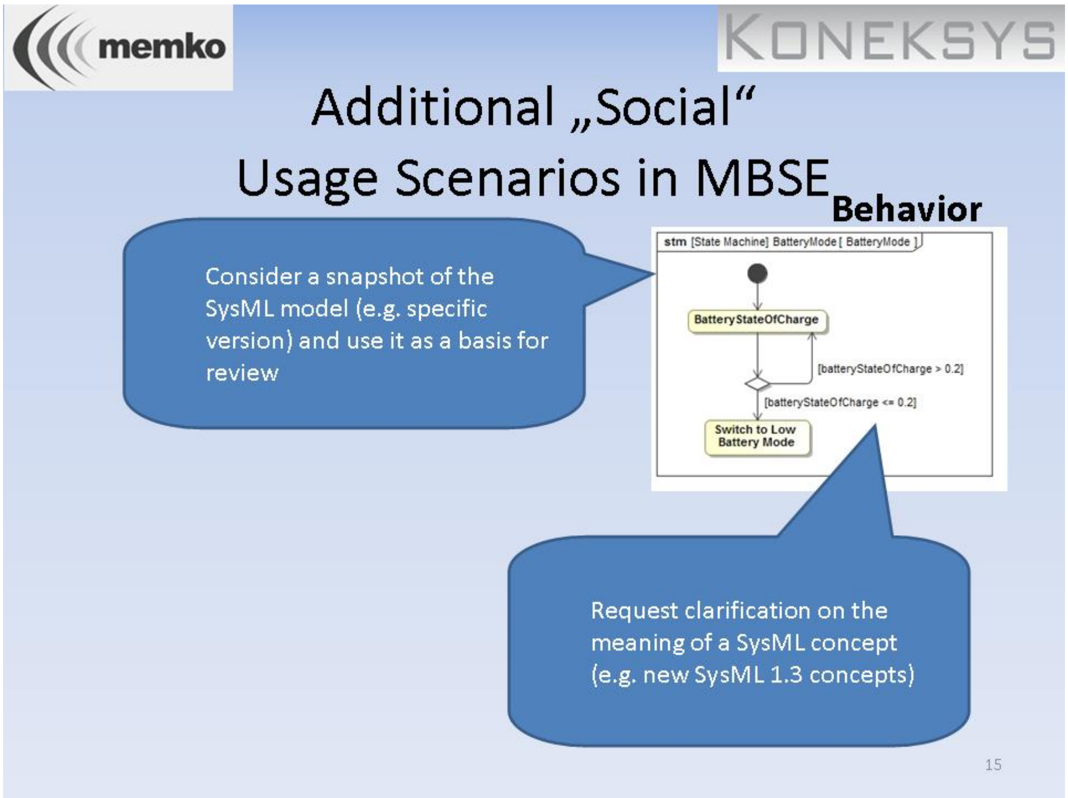
Usage Scenarios in MBSE
Question the value of a SysML diagram (e.g. to avoid modeling just for the sake of modeling)
Request references to further documentation on a SysML feature (e.g. Word document)
Requirements
req [Model] Data [Requirements]
«requirement»
Autonomy
Id = "1"
Text = "The vehicke shall be able to drive long distances without recharging batteries"
«deriveReqt»
«requirement»
BatteryStateOfCharge
Id = "2"
Text = "The battery state of charge shall be above 80% after the New European Driving Cycle"
14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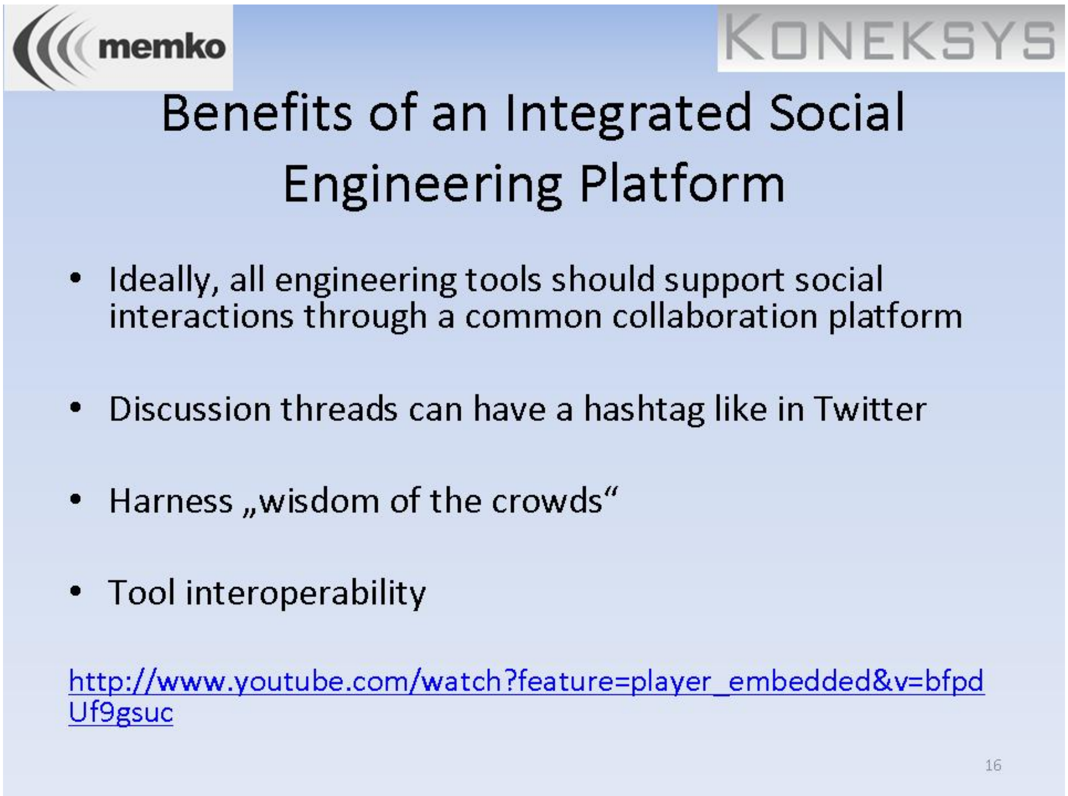
Additional „Social“
Usage Scenarios in MBSE
Behavior
Consider a snapshot of the SysML model (e.g. specific version) and use it as a basis for review
stm [State Machine] BatteryMode [BatteryMode]
BatteryStateOfCharge
[batteryStateOfCharge > 0.2]
[batteryStateOfCharge <= 0.2]
Switch to Low Battery Mode
Request clarification on the meaning of a SysML concept (e.g. new SysML 1.3 concepts)
15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Benefits of an Integrated Social Engineering Platform
• Ideally, all engineering tools should support social interactions through a common collaboration platform
• Discussion threads can have a hashtag like in Twitter
• Harness „wisdom of the crowds“
• Tool interoperability
http://www.youtube.com/watch?feature=player_embedded&v=bfpdUf9gsuc
16

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Roadblock for „Social" Engineering: #1 Company Culture

- Social culture of discussions in engineering
- Cost of setting up and maintaining infrastructure
- Resistance to adopt new technology
- Requirement to adhere to current process, tools, methods
- Fear of leaked Intellectual Property

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Roadblock for „Social" Engineering: #2 Anti-social Engineers

- Engineers typically do not have the best communication skills
- Engineers from different streams find it hard to communicate with each other and with non technical personnel
- Engineers often fail to express their point of view

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Conclusion

- Big potential for MBSE
- But current roadblocks, (e.g. company culture) needs to be overcome, need a paradigm shift
- Current demands of industry require a service oriented approach (consumer centric)

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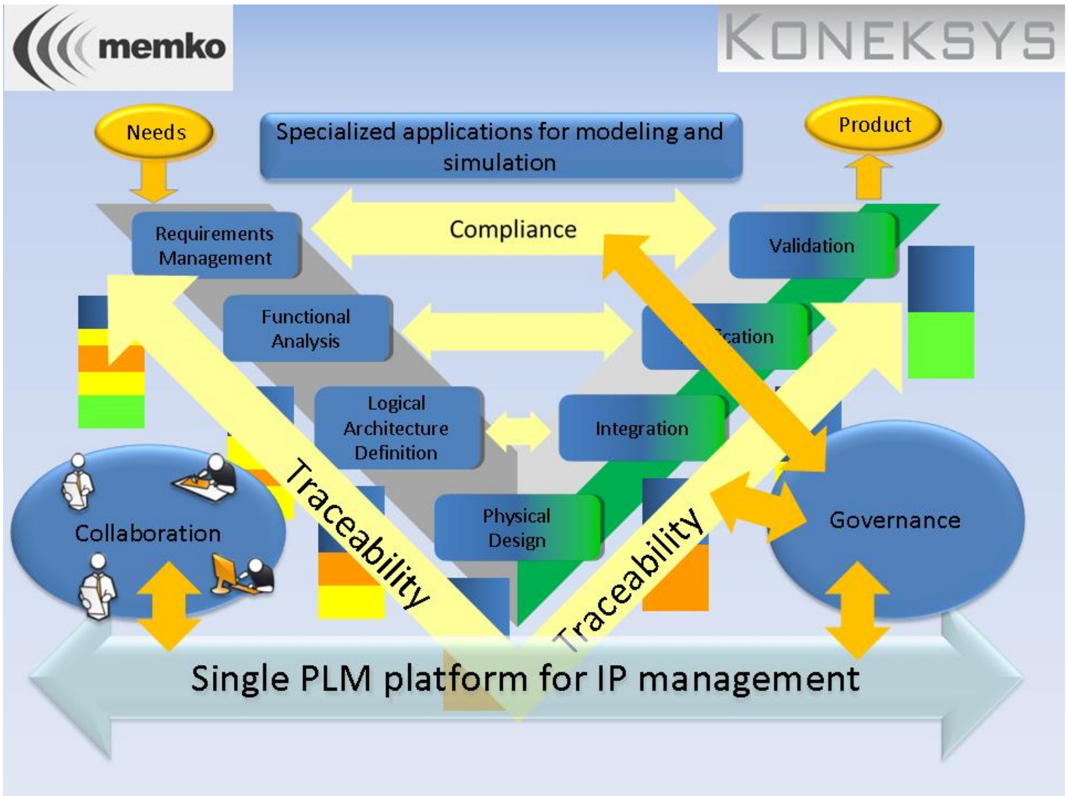

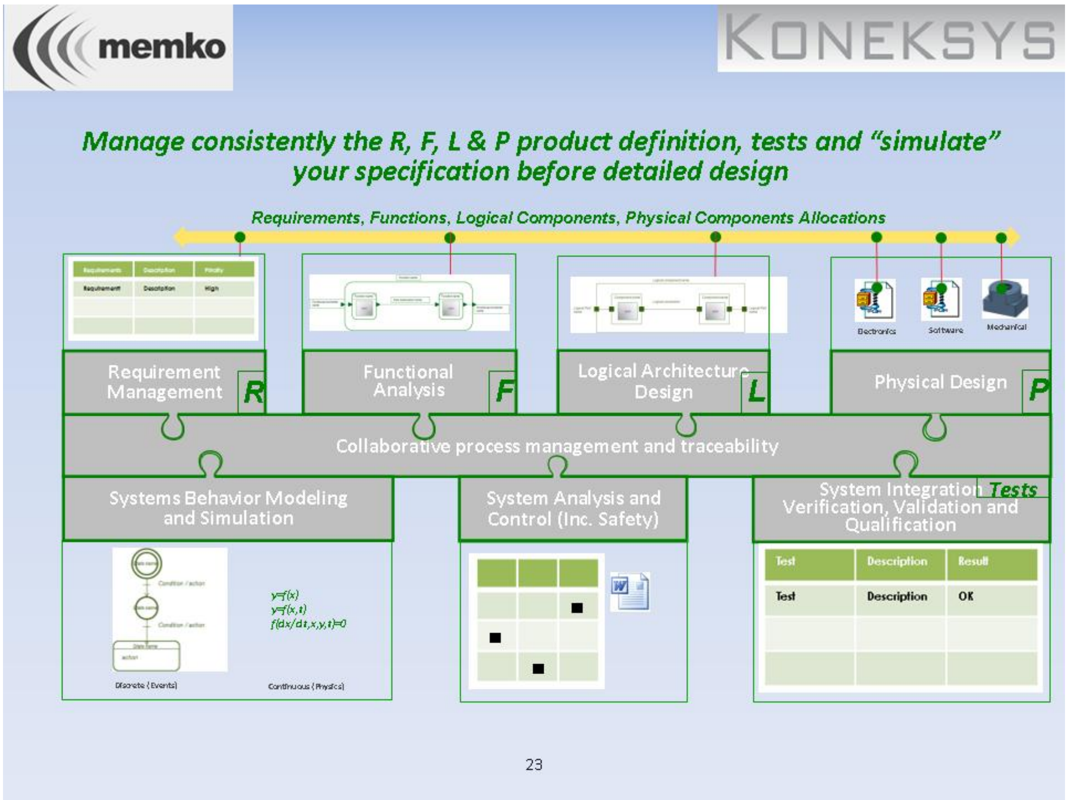
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Manage consistently the R, F, L & P product definition, tests and "simulate" your specification before detailed design
Requirements, Functions, Logical Components, Physical Components Allocations
Requirement Management
R
Functional Analysis
F
Logical Architecture Design
L
Physical Design
P
Collaborative process management and traceability
Systems Behavior Modeling and Simulation
System Analysis and Control (Inc. Safety)
System Integration, Verification, Validation and Qualification
Tests
Test
Description
Result
OK
23

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"…the future of systems engineering can be said to be model-based" according to the International Council on Systems Engineering (INCOSE) vision for 2020. Within Australia, Model-Based Systems Engineering (MBSE) is emerging on a greater number of projects and across a broader range of organisations.

The 2012 MBSE Symposium explored the innovative application of MBSE methodologies to Concept Engineering. Concept Engineering can be described as the application of systems engineering principles, processes, methods, techniques and tools to the identification and analysis of the needs of capability users and other stakeholders.

The symposium included two keynote presentations and fifteen presentations from DSTO, industry and academia. It also included two workshop sessions that explored the use of capability system models as part of the contracting process.